Skeena River Sockeye Escapement and Distribution

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ABSTRACT

Population estimates made from observations on the number of sockeye salmon in the various spawning streams of the Skeena River, B.C., during the period 1944-48 are presented. The methods used include a fence count at Babine Lake, the most important spawing area, supplemented by stream counting in the other areas and sample tagging at Lakelse. Estimates made at Babine by the latter methods were compared with the fence counts; the stream count estimates were about one-third of the actual number present, whereas estimates from tagging were about twice the actual.

A brief description of the spawning streams of the Skeena is accompanied by a map showing their location. Best estimates of 1946-47 escapements to major spawning areas are: Babine, 480,000; Morice, 70,000; Bear, 42,000; Lakelse, 29,000. These comprise 92 per cent of the total for the river system. The area of the spawning beds used by sockeye in the system is about 100 acres, or of the order of 1.5 square yards per spawning pair. The division of the whole run is approximately 45 per cent to the commercial fishery, 6 per cent to the Indian fishery, and 49 per cent escapement.

INTRODUCTION

THE NEED for adequate statistics in assessing the status of any fishery has been increasingly apparent. To answer questions pertaining to possible decline in commercial catches, or interrelation of egg deposition and adult returns, reliable information on the number of fish surviving to maturity is of prime importance. For the highly valuable sockeye salmon (*Oncorhynchus nerka*) of the Pacific coast, all of which die following their single fresh-water spawning run, variation in the annual catch might be expected to be a rough measure of variation in the total maturing population. However, catch figures for the Skeena River, B.C., show no significant relation to spawning ground estimates ($r = +0.38$; $P.05 = 0.51$; Brett, 1950a). In order to draw any conclusions on the success of a particular year's spawning, escapement records of accuracy comparable with catch figures are necessary.

In undertaking to make a biological survey of the Skeena River (Pritchard, 1947b) the Fisheries Research Board of Canada was confronted with the problem of escapement determination. During the first five years of investigation (1944-48) a large proportion of the time was devoted to this endeavour. A steady improvement in technique and expansion of the area covered has done much to provide greater accuracy, yet room for improvement is quite apparent. The following report has been prepared to make these data available and to provide a figure which is, of necessity, a product of opinion as well as empirical count. It presents (1) the various methods employed for determining the escapements to each known spawning area, (2) the spawning estimates made for the years 1944 to 1948, and (3) maps of the sockeye distribution in the Skeena watershed.

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METHODS OF ESTIMATION

Methods of estimating spawning salmon range from making spot counts and eye appraisals of the number on major spawning beds to recording an actual count by means of a fence or weir. On the Skeena River all general surveys have relied on stream counting as a basis for estimating a total run. Some regions like Kitsumgallum Lake have been visited once per year at a time when the run was reported to be at its peak. This particular region, like Morice Lake, is characterized by heavily silted creeks which obscure the salmon. The counts at best are minimal and it is up to the observer to judge what the total run might be from these scant data. In another area, like Lakelse Lake, where visibility is good in practically every case (temporary turbidity in some creeks) and repeated visits can be made, much greater opportunity for accuracy of estimation is provided.

Although a considerable variety of conditions was encountered in the spawning streams of the Skeena, the sockeye habit of spawning in the relatively small streams occurring above lakes made it possible to inspect the majority of these by wading. With the exception of three rivers (Babine, Fulton and Morice), the average widths for the spawning areas of the 36 streams listed in Table IV is 7.7 yards (7.0 metres). Sockeye are frequently observed holding over in pools but spawning appears to be mainly restricted to depths within wading limits. Either permanent (Babine and Lakelse Lakes) or seasonal camps (Alastair, Bear, Kitsumgallum, Kitwanga, Morice, and Morrison Lakes) were established at most of the lakes with runs of 5,000 sockeye or more, so that subsequent inspections of shorter duration provided estimates drawn up by comparison with more extensive surveys.

The frequency with which streams must be visited is problematical. The interval of inspection should be determined from the duration of stream life of the species of salmon, particularly if those counted cannot be marked in some practical manner. If the stream is observed every ten days to two weeks (the average stream life of a mature sockeye) then an additive total of the *living* fish provides the result. If the frequency is greater, the estimate becomes some fraction of the total, while if the frequency is less it becomes some multiple of it.

Total counts of *dead* fish, even in small streams where careful removal or marking has been employed during repeated visits, show discrepancies with counts from *live* fish. In larger streams with deep pools, counts of dead fish are virtually impossible.

Only in one particular case on the Skeena has the accuracy of the stream counting method been put to a direct test. In 1946 an adult counting fence was completed across the Babine River (Figure 1). The stream observations were carried out in that year and 1947 in exactly the same manner as for past years and for similar type counts in other areas. The discrepancy obtained was:

Year	*Total stream count*	*Total fence count*[a]	*Discrepancy*
1946	207,200	455,700	54 per cent
1947	240,700	495,600	51 per cent

[a]Less Indian catches.

The observed estimate from stream counts is only about one-half the actual total. The reason for such a difference is somewhat of a mystery. That stream counts will be minimal is apparent by their very nature, but the discrepancy is beyond such expectations. No lake spawning has been observed, nor any stream left uninspected. It would appear that when large numbers of fish are present in single streams, considerable error may be introduced despite conscientious effort.

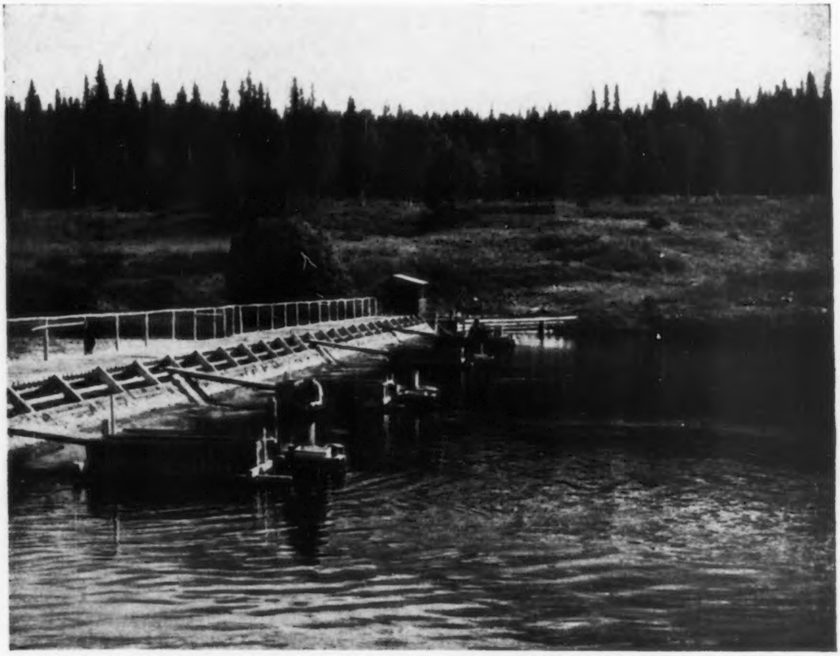


FIGURE 1. Upstream side of the counting fence across the Babine River. Glass viewers placed over white chutes were used to facilitate counting.

Each year at Lakelse Lake a system of tagging a number of adults (usually about 1,000 to 2,000) and releasing these to mingle in the lake with the total population was used to make a simple calculation of the run (Pritchard and Brett, 1945). It presupposes (1) that the fish obtained for tagging are not selected, (2) that these tagged fish become randomly distributed throughout the population, (3) that the addition of the tags does not materially affect the fish either in migratory habits or in survival period, (4) that a tagged fish is neither more readily nor less readily observed than an untagged one, and (5) that tags are not lost, nor are tagged fish selectively removed, between time of tagging and time of counting. To date it has been concluded that these assumptions were fairly well founded at Lakelse Lake, a small, shallow, uniform lake. The tagging operation was performed on fish seined from schools in Blackwater Bay when the

majority of the total run had entered the lake. Within a few days tagged fish have usually been observed or caught at the opposite end of the lake scattered throughout a school. In addition it seems improbable that the experience of being tagged is one which seriously affects adult salmon when the period between tagging and spawning is only a matter of a few weeks. They are capable of surviving the most gruelling of water courses prior to spawning and the insertion of a tag would appear to be a minor trial by comparison with the major adversities which they survive. In stream surveys at Lakelse the attempt was made to observe or handle every fish. It was felt that the presence or absence of a tag did not affect the probability of observing either the fish or the tag.

Efforts have been made to check this system at Lakelse through the introduction of an adult fence. The fence itself has proven to be inadequate for satisfactory operation, so the absolute test has yet to be performed. At Babine Lake, however, the results from proportionate tagging were checked. During two years of operation when complete enumeration of the run was possible, tags were affixed to sockeye salmon proportionately throughout the migration. In 1946 the number tagged on any given day was one-fiftieth of the number passed through the weirs on the previous day. This one day lag was shortened to half a day in 1947 and the proportion changed to one in one hundred.

In Table I the observed and calculated totals are presented. These figures will be found to differ slightly from those listed in other reports as they have been adjusted for Indian catches. An Indian fishery operates in the Babine River a few miles above the point of tagging and at several points on the lake. A record of these catches has been deducted to provide the number of tagged and untagged fish which travelled unmolested to the spawning grounds.

TABLE I. The number of sockeye (less Indian catches) observed at Babine Lake in 1946 and 1947.

	1946			1947		
	Untagged	Tagged	Total	Untagged	Tagged	Total
Number present in the lake	447,372	8,281	455,653	491,303	4,257	495,560
Number observed						
1. Live in streams	120,810	1,074	121,884	103,872	450	104,322
2. Dead in streams	49,287	517	49,804	34,878	248	35,126
Calculated total						
1. From live tag ratio			931,500			982,600
2. From dead tag ratio			789,000			598,700

These figures demonstrate that an error of as much as 100 per cent can occur from using ratios based on live tagged fish and that although the dead tagged observations give a better assessment they may also err from 22 per cent

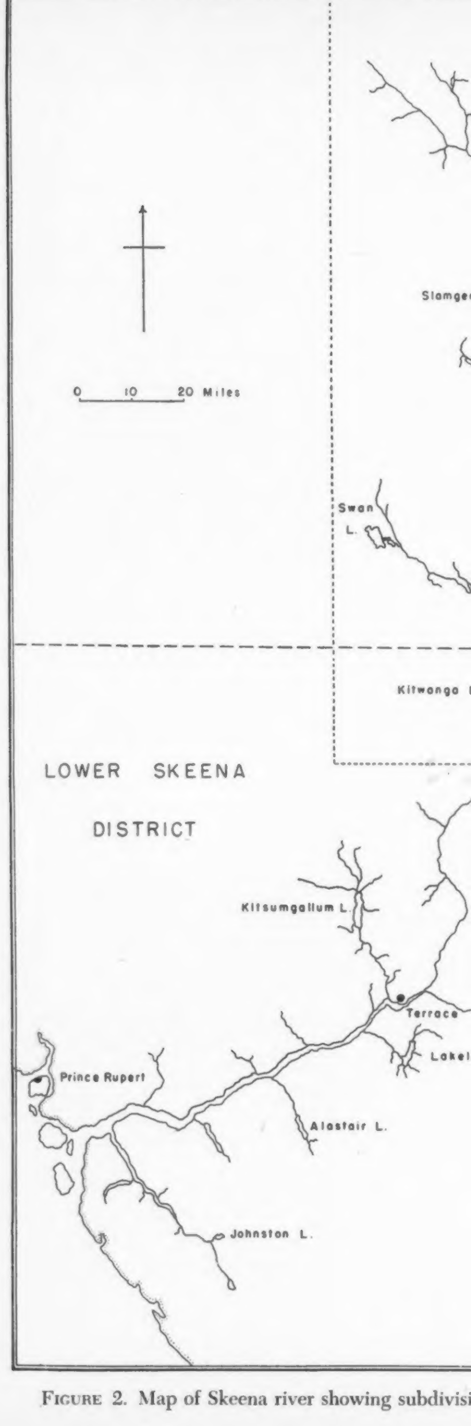
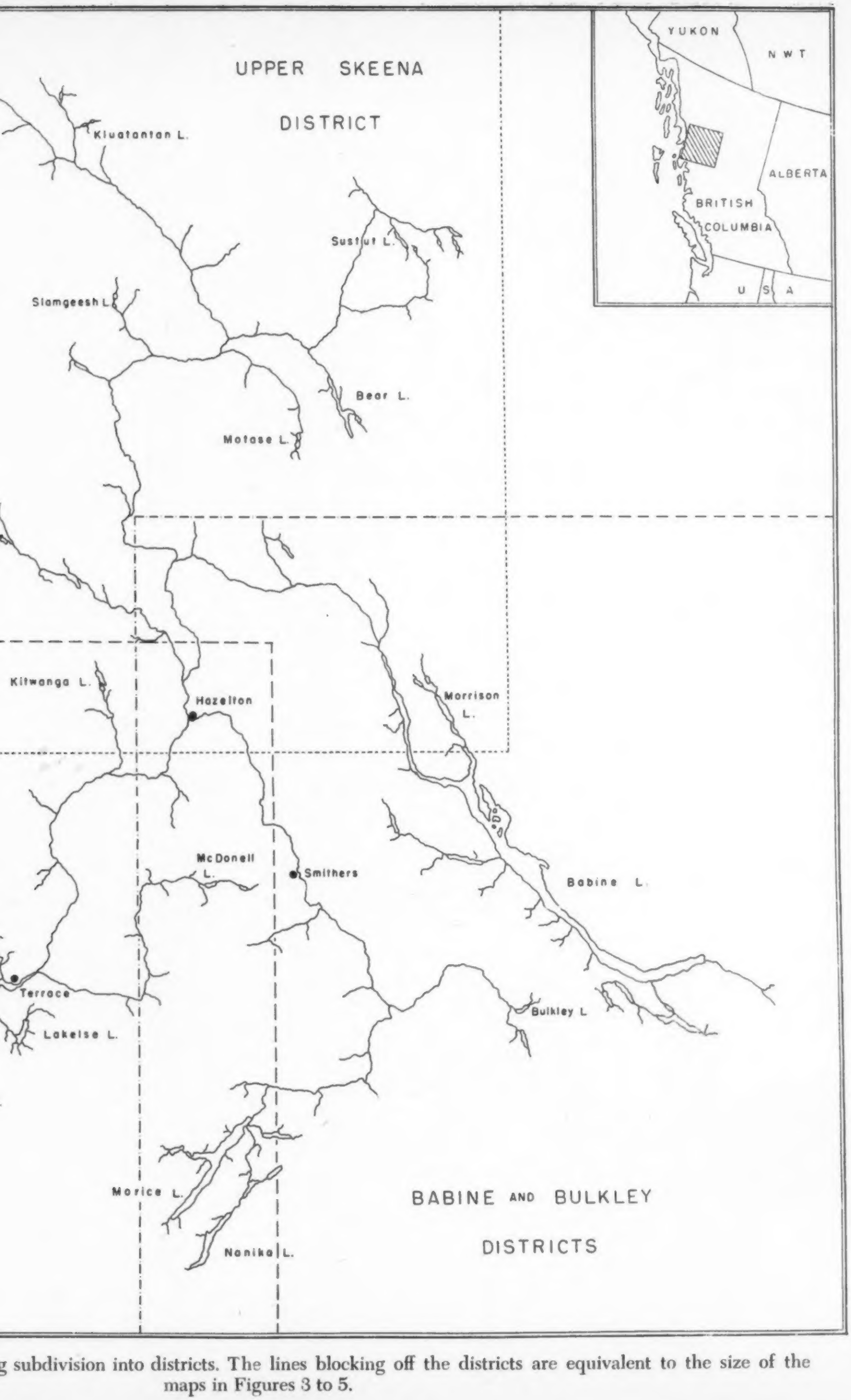


FIGURE 2. Map of Skeena river showing subdivisi



g subdivision into districts. The lines blocking off the districts are equivalent to the size of the maps in Figures 3 to 5.

(1947) to 77 per cent (1946). From the known ratio of tagged to untagged in the lake for 1947 the number of dead tagged sockeye expected to occur in an observed stream total of 35,126 equalled 302. The actual was 248. By a chi-square test this is significantly different from the expected ($P=.01$) so that even the best assessment indicates that some factor, or factors, affects the distribution or observation of tagged fish under the conditions at Babine Lake. The fence is well constructed and has provided no reason to consider it other than fish tight; nor has there been any indication of lost tags.

This result would appear to discredit the evaluations made at Lakelse Lake, which cannot be denied. However, certain differences exist in the two cases which may account for some of the error found at Babine Lake. Babine is close to 100 miles in length with an irregular shore line (Withler *et al.*, 1949) while Lakelse, as stated, is small and comparatively uniform (Brett, 1950b). The chances for variation to occur in Babine with a much greater distance between point of tagging and point of recapture may make a significant difference if distance proves to be an influencing factor.

OBSERVED DISTRIBUTION AND ESTIMATES OF SPAWNING

For convenience in presentation, the Skeena River drainage has been divided into four districts, namely, the Lower Skeena, the Upper Skeena, the Babine and the Bulkley (Figure 2). Each district is dealt with separately. Estimates for the runs to the known spawning streams, with the condition and probable area of the spawning grounds are included in Table IV.

Lower Skeena

From its outlet near Prince Rupert to the first point of major stream division at Hazelton the Skeena River lies in a N.E.-S.W. direction with inflowing streams mainly at right angles to this axis. Despite the many such streams there are only a few scattered lakes to interrupt their flow and, of these lakes, only six have been found to support sockeye in the Lower Skeena area (Figure 3). In order of location from west to east they are:

1. JOHNSTON LAKE, located in the Ecstall River drainage, is just beyond tidal influence. Sockeye have been observed spawning on a few gravel bars in the lake. No recent records point to a more extensive spawning area although a background of intensive commercial fishing may have reduced the numbers and hence the apparent spawning beds. Prior to 1936 gill-netting was permitted in the Ecstall River. From counts of sockeye spawning around the shores of the lake in late August, 1946, a limit of 1,000 was assigned as a total run to this area. At present there seems no reason to believe the run would exceed such a figure.

2. ALASTAIR LAKE, located on the south side of the Skeena River just over 40 miles from the coast, drains into the Skeena via the Gitnadoix River. Two unnamed streams both support an early (August) and late (October) run of sockeye. One, a branch of the other, provides about three-quarters of a mile of good spawning grounds. To this may be added one mile of excellent gravel

in the larger stream. For convenience these have been labelled "South End" creeks. A very small creek ("West Side" creek) close to the south end of the lake supports a surprising number of sockeye for its limited size. Repeated visits will be necessary to establish the occurrence of both early and late runs.

3. LAKELSE LAKE, located on the south side of the Skeena and 12 miles by road from the town of Terrace, is drained by the Lakelse River. For its area (5.47 square miles) Lakelse Lake supports one of the largest sockeye runs in the Skeena system. Its major spawning stream, Williams Creek, has excellent beds of medium coarse gravel. A branch creek (Eliza Creek) provides additional gravel beds for sockeye entering the former. Of the remaining eight streams only Scully Creek to the south maintains a noteworthy run, and Granite Creek has had a varied history of supporting a few thousand spawners down to the present few hundred. The temporary operation of a hatchery followed by stream obstruction near the outlet have been important factors affecting Granite Creek. The remaining streams account for so few sockeye they do not warrant separate mention. The total Lakelse run has been estimated at from 15,000 (1948) to 57,000 (1945). Releasing tagged fish has helped confirm these figures, as has comparison with more complete data obtained in 1939, the only year when a counting fence was operated in Williams Creek (Pritchard and Cameron, 1939). On this occasion a count of 24,085 sockeye was obtained at the fence and an estimate of between 33,000 and 40,000 made for the complete run to the lake.

4. KITSUMGALLUM LAKE, located on the north side of the Skeena and almost on the same parallel of longitude as Lakelse Lake, is drained by the Kitsumgallum River. The lake is very opaque as a result of a heavy suspension of silt discharged by most of the inflowing streams. Those which run off the east and west slopes are too precipitous or too silted for sockeye spawning. The remainder enter at the north end and, either from silting or sluggish flow (Beaver River), offer comparatively limited spawning for the size of the streams. For nearly a mile along the northeast shores of the lake a few hundred sockeye can be observed spawning each year. Good gravel beds and a seepage of clear water characterize this shoreline.

5. MC DONELL LAKE, located in the headwaters of the Copper (or Zymoetz) River, is over 60 miles by water from the Skeena River. It is the largest of a series of three lakes, two of which (Denis and Aldrich) lie beyond McDonell Lake and are connected with it through the extension of the Copper River. Sockeye spawning is confined to scattered beds over three to four miles in the middle of a nine-mile stretch between McDonell and Denis Lakes. A few sockeye pass through Denis Lake and spawn in the lower end of the connecting link between it and Aldrich Lake.

6. KITWANGA LAKE, located north of the Skeena River and on the western margin of the Interior Plateau, is connected to the Skeena by the Kitwanga River. The one main tributary to the lake enters at the northeastern margin from extensive muskeg and willow flats. This unnamed creek (referred to as "North End" Creek in Figure 3 and Table IV) is slow-flowing and about five feet deep at its outlet. Repeated efforts to discover how effective this stream was for spawning

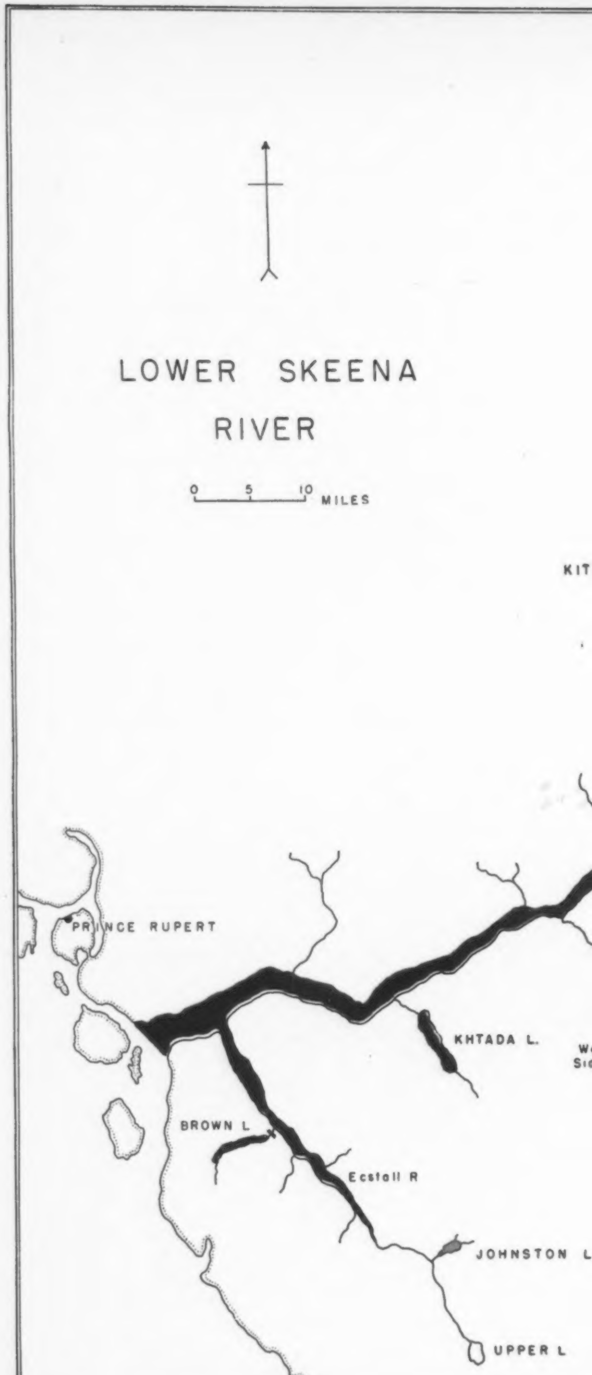
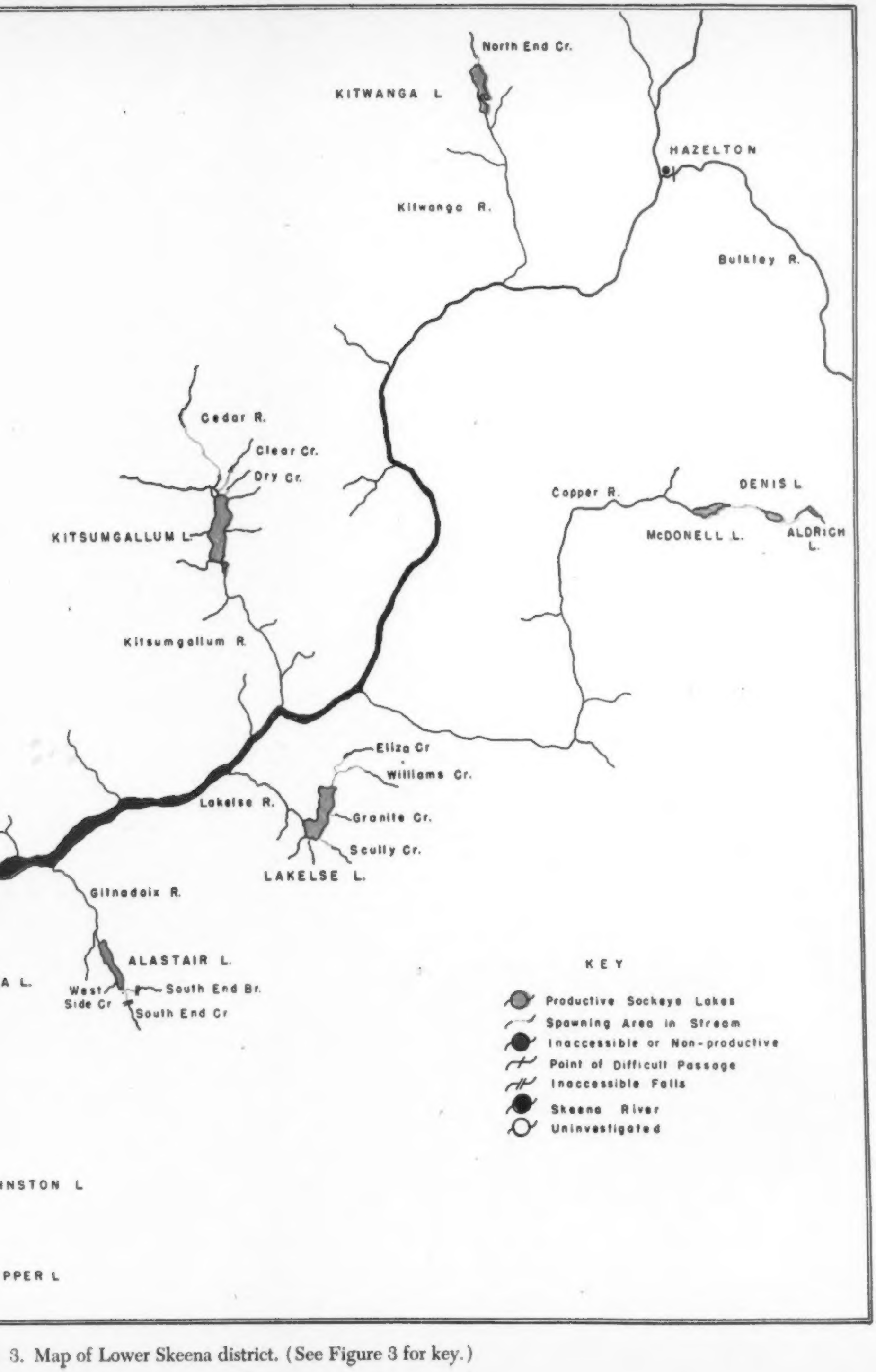


FIGURE 3. Map o



3. Map of Lower Skeena district. (See Figure 3 for key.)

have never revealed more than a few hundred sockeye in its lower reaches. The conclusion has been that the many hundreds of sockeye which enter the Kitwanga River and successfully escape the Indian fishery en route must spawn in the lake. Spawning beds have never been discovered in the lake but ripe sockeye have been netted at various points and old carcasses reported drifted ashore. Some indication of the run can be had from Indian catch records and from counts made of sockeye moving over shallow bars in the Kitwanga River.

The sockeye spawning in the Lower Skeena area can be summed up as mainly confined to eight creeks tributary to four lakes, with two lakes providing additional spawning beds along their shores. Williams Creek at Lakelse Lake is probably the most important, but the "South End" creeks of Alastair Lake may better the former in some years. Not one of these lakes exceeds 7 square miles in area and the average is 4.3 square miles. Thus, the total lake area relative to sockeye spawning is not great.

UPPER SKEENA

The portion of the Skeena which drains the northern limits of the watershed has often been called the Upper Skeena (Figure 4). Merging with the flow from Babine Lake to the southeast it joins the Bulkley River to form the Lower Skeena. At this junction the town of Hazelton is located, marking the former limit of upstream shipping by the stern-wheelers which used to navigate the Skeena. The first tributary of importance to the Upper Skeena is the Kispiox River, at the head of which a series of small lakes is situated. These lakes and the remaining lakes carrying significant runs of sockeye in the Upper Skeena district are considered briefly below.

1. The LAC-DA-DAH basin, the Indian name given to the chain of lakes at the upper limit of the Kispiox River, includes SWAN, CLUB and STEPHENS LAKES. They drain in this order into Stephens Creek which meets the Kispiox River about 60 miles from the Skeena. In this group only two significant spawning grounds have been located and these are quite limited in area. The uppermost is that in Falls Creek, a small stream with spawning restricted to a lower 450 feet of stream bed by a series of impassable falls. The second is in Club Creek lying between Club Lake and Stephens Lake. The gravel in the lower portion of this creek is quite suited to salmon spawning, but the creek is heavily studded with boulders over portions of its remaining course. Oddly enough sockeye can be found depositing eggs in this boulder-strewn section, but the production per unit area must be comparatively low. Two small zones can be added to the above. A few square yards of gravel bed have been observed to carry spawning salmon in the short stretch between Swan and Club Lakes and also in Stephens Creek.

2. Over 150 miles upstream from Hazelton lie two small lakes, DAMSHILGWIT and SLAMGEESH. They are linked together by the Slamgeesh River which continues south for one quarter of a mile to join the Kilankis River and thence discharges into the Skeena. One small stream, Damshilgwit, drains the low flats to the north. Each of these streams, Damshilgwit and Slamgeesh, supports a small

run of sockeye and collectively have been estimated to carry a total run of between two and three thousand. The Kilankis River is heavily silted and has a large falls one half mile above its junction with the Slamgeesh River. Consequently it is of no importance as a sockeye spawning stream.

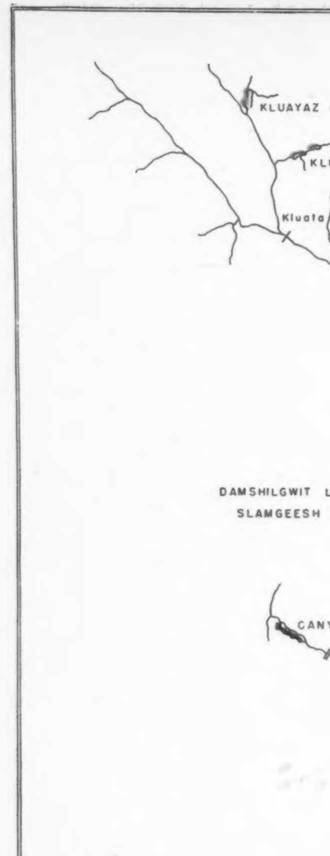
3. The next tributary draining a lake into the Skeena is the Squingula River, east of the Kilankis. A glacier fed lake, MOTASE LAKE, lies in its headwaters. Only coho salmon have been recorded as adults in this drainage and the evidence for sockeye spawning is limited to the identification of one young specimen taken from the stomach of a predator fish. From the nature of its heavily silted streams it seems an unlikely area and has been labelled as nonproductive until further evidence is obtained.

4. Five miles beyond the Squingula River, the Sustut River drains westward from a series of lakes into the Skeena. The largest of these is BEAR LAKE with a small offshoot, AZUKLOTZ LAKE, to the southeast. The difficulty of assessing the intensity of sockeye spawning in this region has been accentuated by what appears to be a high percentage of lake spawning. The remaining sockeye spawning grounds are centered in Azuklotz and Salix Creeks in which 3,600 sockeye were estimated to have spawned in 1945, the majority being in Azuklotz Creek. In peak years other small tributaries may be used. To facilitate estimation of the run, the outlet river was partially blocked by a picket fence and trap in 1947 and more fully blocked in 1948 by the addition of wire screening. Direct counts together with results from a tagging programme at the fence have demonstrated that earlier estimates did not attribute enough sockeye to lake spawning, which is now thought to account for as many as 40,000 sockeye in some years.

5. The contribution from the remaining lakes in the Sustut River system (JOHANSON, DARB, SPAWNING, SUSTUT and ASITKA LAKES) is even more difficult to assess. Spawning appears to be entirely confined to the lakes. Of the five lakes inspected only a few spot counts near shore could be made. Even the largest of this group (Sustut, with area 1.3 sq. mi.) is only a fraction of the area of Bear Lake (7.2 sq. mi.) and it would seem quite unwarranted to attribute much of an escapement to such limited grounds despite the lack of exact information. A liberal estimate of 5,000 has been included in Table IV.

6. The most northerly area in which sockeye have been located is tributary to the Kluatantan River, a branch of the Skeena some 50 miles northeast of the Sustut River. Heavy silt has so limited observation that no first-hand report of where spawning occurs has been obtained. A few sockeye were netted in KLUAYAZ LAKE and patches of gravel suitable for spawning noted above and within the lake. Another possible spawning area is that beyond KLUATANTAN LAKE which forms a second and lower branch of the Kluatantan River. With so little exact information the Kluatantan system has not been included in Table IV.

The relatively heavy preponderance of lake spawning in the Upper Skeena drainage contrasts with the very limited stream spawning. Only Falls Creek (Stephens Lake), Club Creek (Club Lake) and Azuklotz Creek (Azuklotz Lake) have been observed to carry sockeye runs which exceed 1,000. The lakes


KLUAYAZ
Kluatа
DAMSHILGWIT L
SLAMGEESH
Falls Cr
CLUB L
SWAN L
STEPHENS L
Stephens Cr
Kispiox R

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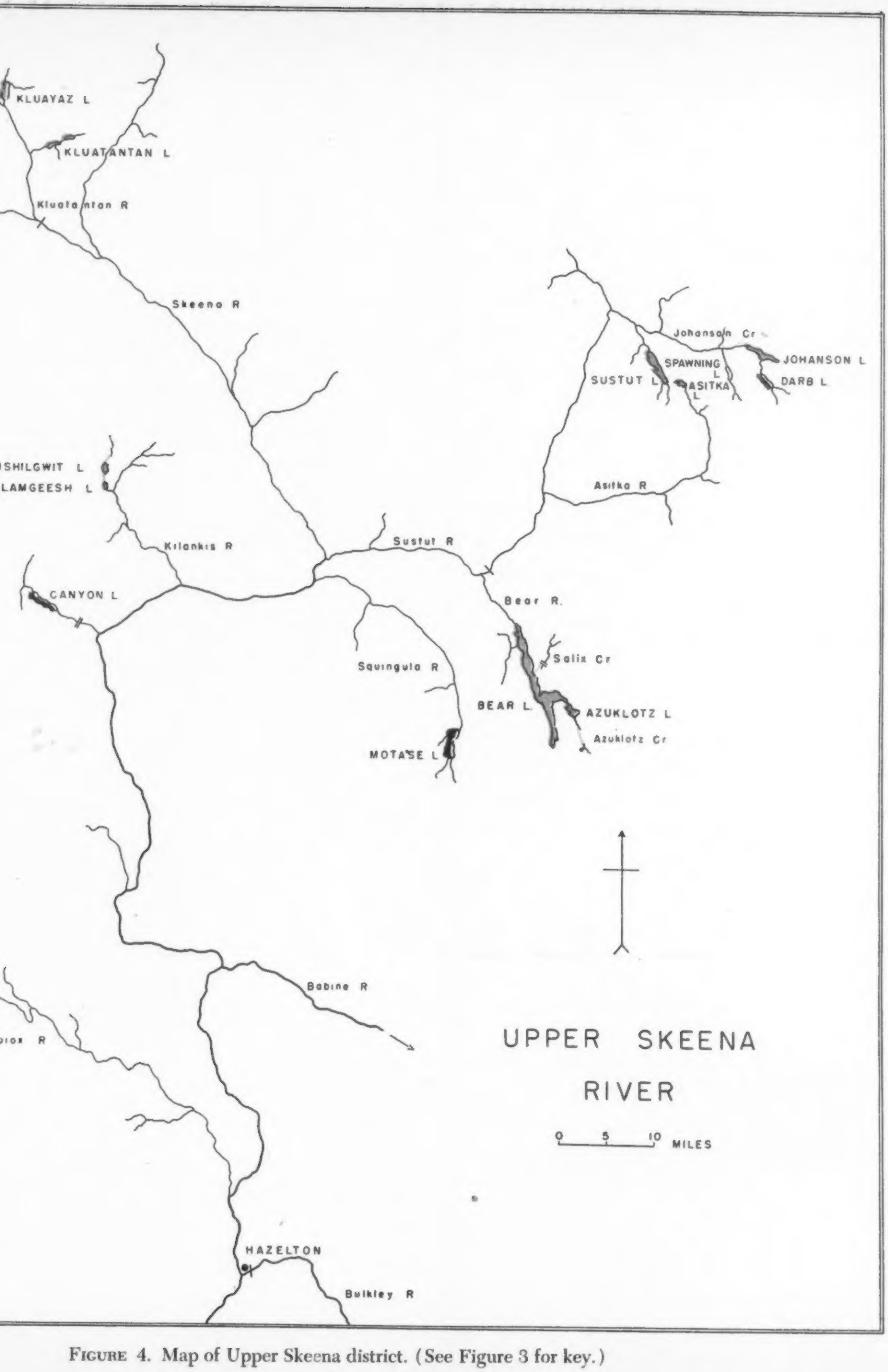

FIGURE 4. Map of Upper Skeena district. (See Figure 3 for key.)

themselves are small and scattered, and much of the whole area typical of a mountainous country with fast flowing streams, heavy silting and rapid erosion. Too little is known about the requirements for and success from lake spawning. Spring seepage of oxygenated water through gravel beds would appear to be a prerequisite. Low oxygen concentrations from organic decay in lake bottoms, coupled with silt deposition, must restrict the depth of spawning success. In general, the sockeye spawning areas of the Upper Skeena do not exhibit as promising an outlook for fish cultural development as those located elsewhere in the watershed.

BABINE

1. By far the largest lake in the Skeena system is BABINE LAKE (Figure 5) with a maximum length of 92.5 miles and an area of 171.8 square miles. Its relative importance as a source of spawning grounds is in proportion to its size. It lies in a valley almost parallel to the valley of the Bulkley River but separated from it by an extensive mountain range of 5,000 to 7,500 feet in height. The northeastern slopes of this range are drained by a number of streams which in most cases flow directly into the lake and provide most of the spawning grounds for a run of sockeye which has exceeded half a million in some years. The outflow of the lake is via the Babine River through Nilkitkwa Lake at the northwestern extremity. One-half mile downstream from this small lake the counting fence was constructed through which the complete run to Babine Lake has been enumerated.

In describing the spawning streams which drain into the lake, Withler *et al.* (1949) have stated that:

> They consist of good, fine to coarse, gravel bottoms free of glacial silt. They are not subject to the extreme freshets of the coastal area nor is there any evidence of extreme scouring. Some, such as the Fulton River, where more than 150 million eggs are deposited after a normal run, drain a group of lakes in the hills surrounding Babine and consequently maintain a fairly regular flow of water. These large rivers, Fulton, Morrison and Pinkut, are the most important spawning streams. Small creeks such as Five-mile and Nine-mile, not having the advantageous reservoir of lakes at the headwaters, are more subject to the extremes of high water during the spring break-up and of low water during the summer. The effects of such variations in water level are probably serious only in the years of unusually heavy or unusually light rainfall.

In the Babine River, between Babine Lake and Nilkitkwa Lake, and for one third of a mile below Nilkitkwa Lake, two large spawning grounds occur where the majority of the late-run sockeye spawn. Estimation of the number of sockeye in these areas has always been difficult because of the width of the river and rapid flow. Observations indicate, however, that in some years spawning in these grounds is important.

2. MORRISON LAKE drains into a northeastern arm of Babine Lake through the Morrison River. Two creeks, Haul Creek and Tahlo Creek, enter this lake at its upper end, arising from small lakes of the same names. Only Tahlo Creek has been found to carry a scattered population of spawning sockeye, above and below TAHLO LAKE. The sockeye fry which spend one or more

years in Morrison Lake are probably derived from some of the upper spawning grounds of the Morrison River as well as from Tahlo Creek.

The wealth of stream spawning beds present in the Babine area contrasts with the condition found in the Upper Skeena and in the Bulkley area to follow. Heavy suspension of silt in each of the other systems can be observed in many of the rivers, but not so in Babine. One main spawning limitation for the Babine area is the termination of many of the gravel beds by impassable falls. Lake spawning has not been observed to account for an appreciable number of sockeye although this does not eliminate it as a possibility. With the addition of the counting fence across the Babine River, a total enumeration of the sockeye has been possible regardless of the destination.

Bulkley

The largest branch of the Skeena is the Bulkley River (Figure 5). It shows a 19-year mean monthly discharge of 9,240 sec.-ft. near Hazelton at its point of confluence with the Skeena (Anon., 1946). This is about one-third of the mean monthly discharge recorded for the Skeena further downstream at Usk. Its main tributaries that carry sockeye are:

1. The Morice River which drains the extensive Morice Lake area including MORICE, ATNA, NANIKA, KIDPRICE, STEPP and MC BRIDE LAKES. With the exception of Morice Lake each of the others is either inaccessible to salmon because of high falls or is unproductive (for example, McBride Lake). Only three sockeye grounds have been located: one in the Nanika River, one in the Morice River just below Morice Lake, and the third in a small stream, Gosnell Creek, tributary to the Morice River 15 miles below the lake. The rest of the area is barren of suitable beds possibly because of the rapid flow and heavy silting of most of the streams. The Nanika River itself is grey and opaque from glacial silt, but, like the Cedar River of Kitsumgallum Lake, it has patches of clear water seeping or running into its flow, and heavy spawning has been observed in these restricted gravel beds. The Morice River is mainly a spring salmon spawning ground, but a few scattered beds are used by sockeye for the first three to four miles below the lake.

2. The continuation of the Bulkley River beyond the Morice River junction leads through a low pastoral valley to a group of lakes, notably BULKLEY LAKE and MAXAM LAKE. In the spawning months of August and September the flow of this river is quite sluggish and the temperature rises considerably above the colder Morice River. A small falls 30 miles from the junction of the Morice and Bulkley Rivers is the only obvious point of difficult passage, where sockeye have been noted jumping in the turbulent waters. Scattered log jams do not add to the ease of passage of the relatively few sockeye that move into this system. The only record of spawning has been that on Maxam Creek between Bulkley Lake and Maxam Lake where some patches of good spawning gravel are present.

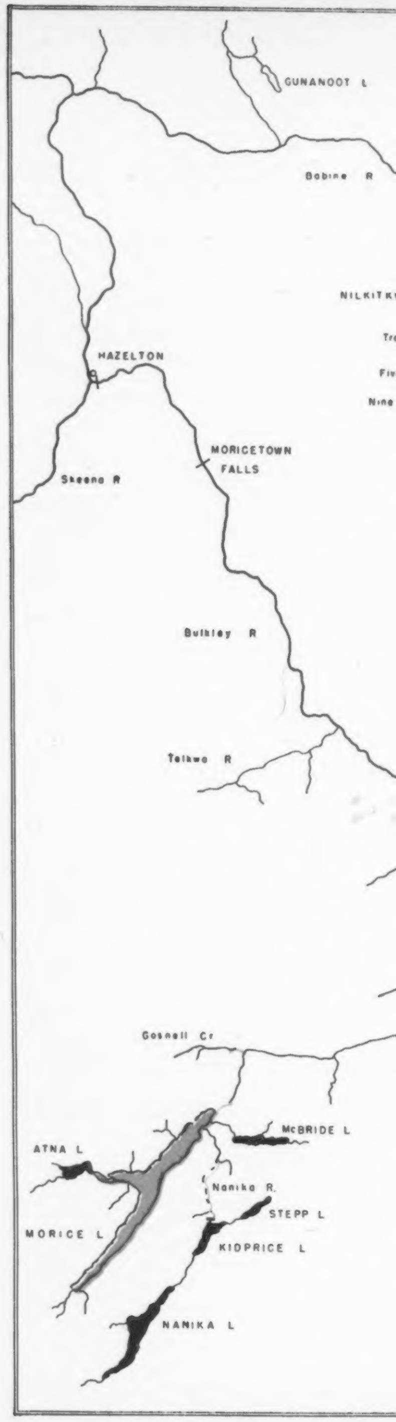
GUNANOOT L
Babine R
HAZELTON
MORICETOWN
FALLS
Skeena R
Bulkley R
Telkwa R
Gosnell Cr
McBRIDE L
ATNA L
Nanika R.
STEPP L
MORICE L
KIDPRICE L
NANIKA L

FIGURE 5.

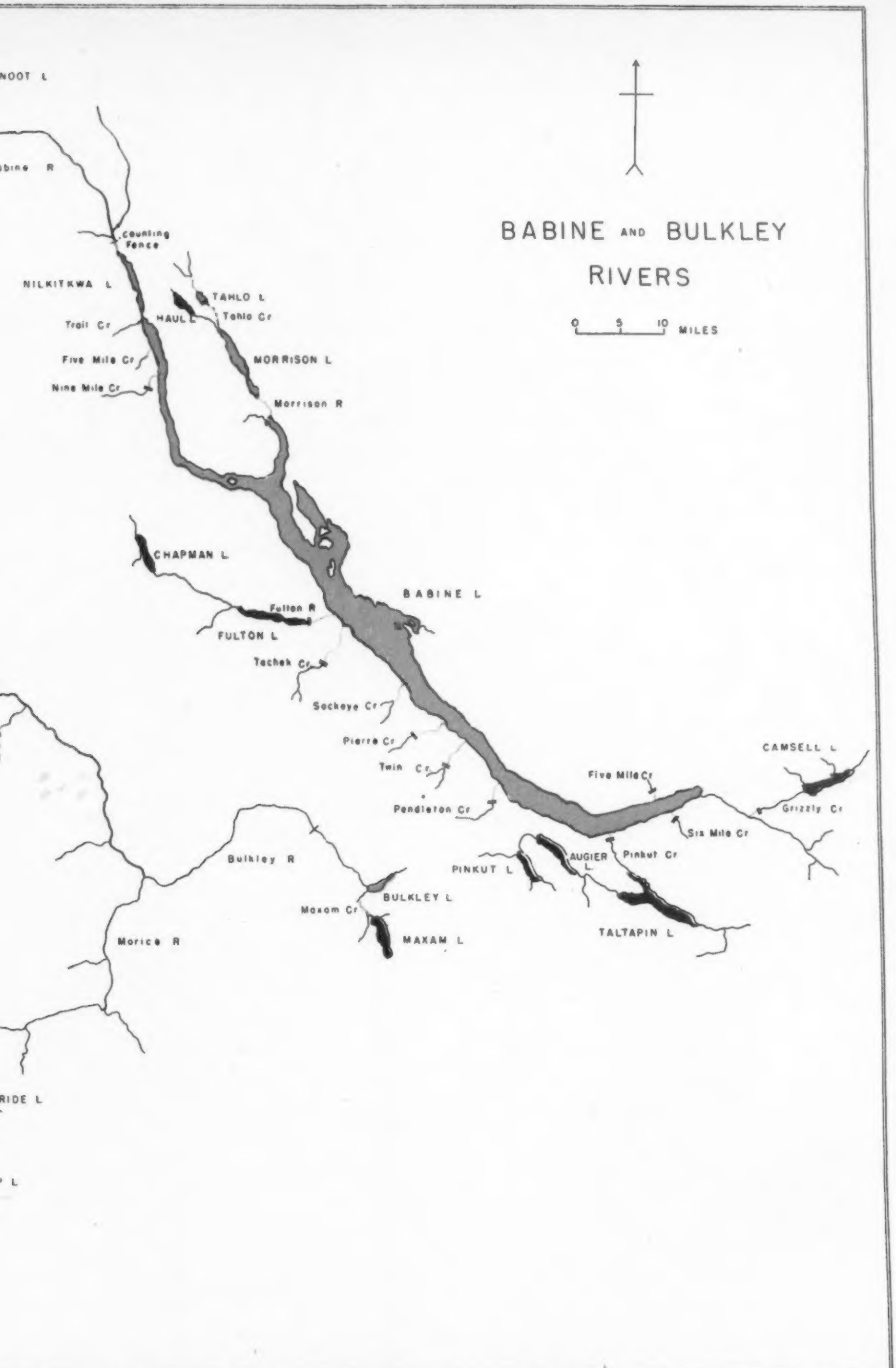

FIGURE 5. Map of Babine and Bulkley districts. (See Figure 3 for key.)

MOST PROBABLE ESCAPEMENT

During each of the five years, 1944 to 1948, sockeye were tagged off the outlet of the Skeena River and a collection of tags was made from recaptures in the commercial fishery, the Indian fishery and on the spawning grounds (Pritchard, 1944, 1945, 1947a, 1948; Milne, 1949). Gill-net fisheries are known to be selective in their catches, and it cannot be assumed that the tagged fish become randomly dispersed throughout the fishery. These two features alone considerably reduce the significance of results calculated from tagging returns. Neither is the Indian fishery a random sampling unit, nor can observations on the spawning grounds be considered very accurate. The significant fact is the recognition of these limitations. Like scattered points on a graph that do do not fit into any mathematical sequence, the data from such fishery investigations have to be weighed in the minds of the investigators and the results set forth with reservation.

At the end of each year's investigation on the Skeena a total escapement was estimated. In 1944 and 1945 the escapements were placed at almost twice that from spawning ground observations and equal to less than half that from tag return calculations. When the results from the Babine fence count were obtained in 1946 and found to be close to twice the total from spawning ground reports, concrete evidence to support the above opinion was provided. With the encouragement of a prediction come true, these estimates have been made for each year and are presented in Table II.

TABLE II. The most probable relation of the number of sockeye in each of commercial catch, Indian catch and escapement. Figures are quoted in thousands.

Year	1944	1945	1946	1947	1948	Av.	Per cent
Commercial	810	1,200	620	390	1,200	840	45
Indian	90	150	75	70	150	110	6
Escapement	620	1,400	680	690	1,200	920	49

The best approximations and actual count (Babine Lake) of the escapement to each of the sockeye producing areas for 1946-47 are recorded in order of magnitude in Table III. The first four escapements listed (Babine, Morice, Bear and Lakelse Lakes) constitute 92 per cent of the estimated total, while Babine and Lakelse, where counting weirs are to be in operation, account for about 75 per cent. A good index of the annual escapement can therefore be had from these two sources and additional evidence supplied from observations at Moricetown Falls on the Bulkley River.

Table IV is a compilation of every record of sockeye spawning made during the five year period of the investigation. The methods of determination have been discussed earlier. The majority are estimates made from stream counts. Rough maps of most of these streams were made during repeated visits, and the nature of the stream bed together with the incidence of sockeye spawning noted while in the field. From these the stream measurements listed in the

TABLE III. Average escapement of sockeye to lakes in the Skeena River drainage for 1946 and 1947.

Lake	Escapement	Per cent of total
1. Babine Lake	480,000	70.8
2. Morice Lake	70,000	10.3
3. Bear Lake	42,000	6.2
4. Lakelse Lake	29,000	4.3
5. Alastair Lake	22,000[a]	3.2
6. Lac-da-dah Lakes	10,000	1.5
7. Kitsumgallum Lake	6,000	0.9
8. Kitwanga Lake	5,000	0.7
9. Sustut Lakes	5,000	0.7
10. McDonnell Lake	5,000	0.7
11. Slamgeesh Lakes	2,000	0.3
12. Bulkley Lakes	1,000	0.1
13. Johnston Lake	1,000	0.1
Total	678,000	

[a]Visited in 1947 and 1948 only.

appropriate columns have been obtained. They serve as a quantitative description and give a comparative index of the concentration of spawning in the various districts. Unfortunately no area measurements can be quoted for lake spawning.

A precise spawning survey of one stream in the Fraser River drainage, the Chilko River, has been described (Anon., 1949). The number of square yards of gravel assigned to the portions with most concentrated spawning in the Chilko River was 0.62 per sockeye pair. This is close to that for the heavily spawned Falls Creek of Swan Lake (Upper Skeena district) which was calculated at 0.7 square yards. The average area of stream bed used for good spawning on the Chilko was from 1.9 to 4.2 square yards per spawning pair which is quite similar to the Skeena River calculations in Table IV.

If the approximations of spawning area on the Skeena are summed, the total equals about 500,000 square yards (without lake spawning), or about 100 acres. It emphasizes the possibilities of a well planned "farming" programme for fish culture. The contribution of the Babine district to this total spawning area is approximately 60 per cent which, coupled with better than average spawning conditions, supports the estimate made for the number of spawning sockeye (72 per cent total escapement).

ACKNOWLEDGEMENTS

The credit for covering such a large and relatively inaccessible area as that of the Skeena River with a watershed of 19,000 square miles is divided among many observers. The investigation was directed by Dr. A. L. Pritchard who personally visited at one time or another the majority of the spawning streams listed. Many seasonal employees, mostly fisheries students from the University of British Columbia, have assisted the biologists in charge of the different

TABLE IV. The spawning streams in the Skeena River drainage ...

Spawning district	Estimated spawning run from stream counts 1944	1945	1946	1947	1948	Av.	Length of stream used (miles)	Av. width of stream (yards)	Estimated utilization (%)	Spawning area (thousands of square yards)	No. of sq. yds. per spawning pair (av.)	Spawning conditions	Limitation
I. LOWER SKEENA													
1. *Johnston Lake*													
Johnston Lake	—	—	1,000	—	—	1,000	—	—	—	—		Lake spawning	Unsuitable streams
Total			*1,000*			*1,000*					—		
2. *Alastair Lake*													
South End Creek	—	—	—	7,800	17,500	12,600	1.0	12	80	17.		Concentrated spawning in excellent gravel	Falls limit stream length
South End Branch	—	—	—	6,000	12,000	9,000	0.75	4	75	4.			
West Side Creek	—	—	—	200	500	400	0.05	2	70	0.1			
Total				*14,000*	*30,000*	*22,000*				*21.1*	1.9		
3. *Lakelse Lake*													
Williams Creek	20,000	50,000	34,000	15,000	13,000	26,400	3.5	10	65	40.		Quite suitable for good spawning	Boulders and more rapid flow upstream
Eliza Creek	2,000	4,500	4,000	900	800	2,440	1.0	6	50	5.3			
Scully Creek	2,500	2,000	1,800	1,000	1,200	1,700	1.25	5	70	7 7			
Granite Creek	500	500	200	100	0	260	0.25	5	30	0.7			
Total	*25,000*	*57,000*	*40,000*	*17,000*	*15,000*	*30,800*				*53.7*	3.5		
4. *Kitsumgallum Lake*													
Cedar River	6,000	3,000	3,500	2,500	—	3,750	4.0	12	15	12.7		Very scattered in streams	Unsuitable streams
Clear Creek	2,000	1,000	1,200	900	—	1,275	2.0	5	60	10.6			
Dry Creek	200	200	100	100	—	150	0.1	3	50	0.3			Heavy silt and boulders
Kitsumgallum L.	1,800	4,800	2,500	2,500	—	3,575	—	—	—	—		Lake spawning	
Total	*10,000*	*9,000*	*7,300*	*6,000*		*8,750*				*23.6*	9.1		
5. *McDonell Lake*													
Copper River	—	—	3,000	4,000	5,000	4,000	4.0	7	30	14.8		Scattered in streams	Limited suitable gravel
Total			*3,000*	*4,000*	*5,000*	*4,000*				*14.8*	7.4		
6. *Kitwanga Lake*													
North End Creek	—	200	200	100	—	160	—	—	—	—		Confined to lake spawning	Virtually no suitable streams
Kitwanga Lake	—	5,800	3,800	4,900	—	4,800	—	—	—	—			
Total		*6,000*	*4,000*	*5,000*		*4,960*					—		

TABLE IV (*continued*).

Spawning district	Estimated spawning run from stream counts 1944	1945	1946	1947	1948	Av.	Length of stream used (miles)	Av. width of stream (yds.)	Estimated utilization (%)	Spawning area (thousands of square yards)	No. of sq. yds. per spawning pair (av.)	Spawning conditions	Limitation
II. UPPER SKEENA													
1. *Swan Lake*													
Falls Creek	1,000	1,000	1,500	2,500	8,000	2,800	0.1	6	90	1.0		Concentrated spawning	Very limited streams
Total	*1 000*	*1,000*	*1 500*	*2,500*	*8,000*	*2,800*				*1.0*	0.7		
2. *Club Lake*													
Upper Club Creek	10,000	6,000	7,000	8,000	10,000	8,200	1.0	12	35	7.0		Concentrated spawning	Rock and boulders
Lower Club Creek	400	300	400	500	1,000	520	00.1	10	90	0.1			
Total	*10,400*	*6,300*	*7,400*	*8,500*	*11,000*	*8,720*				*7.1*	1.6		
3. *Stephens Lake*													
Stephens Creek	200	50	50	50	50	80	—	—	—	—		Poor	Sand and mud
Total	*200*	*50*	*50*	*50*	*50*	*80*					—		
4. *Damshilgwit Lake*													
Damshilgwit Ck.	—	—	—	1,000	—	1,000	0.5	4	60	2 1	4.2	Fair	One small creek
Total				*1,000*		*1,000*				*2.1*	4.2		
5. *Slamgeesh Lake*													
Slamgeesh Creek	—	—	—	2,000	—	2,000	1.0	8	30	4.2		Fair	Limited area
Total				*2,000*		*2,000*				*4.2*	4.2		
6. *Bear Lake*													
Azuklotz Creek	—	3,000	1,500	3,000	2,000	2,400	1.5	8	40	8.5		Fair stream spawning with lake spawning	Precipitous streams
Salix Creek	—	600	25	50	300	250	0.75	5	10	0.7			
Bear Lake	—	46,400	38,475	39,950	5,700	32,630							
Total		*50,000*	*40,000*	*43,000*	*8,000*	*35,280*				*9.2*	6.9		
7. *Sustut Lakes*													
Lake spawning	—	—	—	—	—	5,000	—	—	—	—		Only lake spawning	Unsuitable streams
Total						*5,000*					—		

Lake spawning	—	—	—	—	—	5,000	—	—	—	—		Only lake spawning	Unsuitable streams
Total						*5,000*					—		

Spawning district	Estimated spawning run from stream counts 1944	1945	1946	1947	1948	Av.	Length of stream used (miles)	Av. width of stream (yards)	Estimated utilization (%)	Spawning area (thousands of square yards)	No. of sq. yds. per spawning pair (av.)	Spawning conditions	Limitation
III. BABINE													
1. *Babine Lake*													
Grizzly Creek	6,000	5,000	3,500	4,900	8,800	5,600	.75	10	65	8.6		Good spawning stream throughout with relatively stable flow and little scouring	Mainly limited by a ridge of land creating impassable falls on most streams
Four-mile Creek	6,000	6,000	1,500	1,800	3,300	3,700	.75	8	50	5.3			
Six-mile Creek	5,000	1,000	500	800	2,700	2,000	.75	6	40	3.2			
Pinkut Creek	6,000	25,000	28,000	25,000	25,500	21,900	.5	14	75	9.3			
Pendleton Creek	500	2,100	2,000	1,800	1,300	1,700	2.0	3	25	2.6			
Twin Creek	15,000	15,500	9,500	10,000	5,100	11,200	4.0	9	55	32.			
Pierre Creek	15,000	17,000	16,000	19,000	19,600	17,300	4.0	9	70	44.			
Sockeye Creek	2,500	500	500	1,500	600	1,100	1.25	3	40	2.6			
Tachek Creek	15,000	12,000	6,500	12,000	5,700	11,200	4.5	10	65	52.			
Fulton River	60,000	70,000	100,000	115,000	115,000	92,000	3.5	25	40	62.			
Morrison River	15,000	24,000	20,000	28,000	30,000	23,400	2.5	12	50	26.			
Nine-mile Creek	8,000	10,000	1,000	600	3,900	4,700	2.0	8	70	20.			
Five-mile Creek	1,000	700	100	200	1,300	700	1.0	3	20	1.1			
Trail Creek	500	100	100	100	0	200	.25	3	20	0.3			
Upper Babine R.	10,000	15,000	9,000	10,000	12,500	11,300	.4	75	30	15.8			
Lower Babine R.	10,000	15,000	9,000	10,000	15,000	11,800	.4	75	30	15.8			
Total	*175,500*	*218,900*	*207,200*	*240,700*	*350,300*	*219,000*				*300.6*	2.7		
2. *Morrison Lake*													
Tahlo Creek	—	—	5,000	5,000	7,000	5,700	—	—	—	—		Scattered in streams	Mud and sand
Total			*5,000*	*5,000*	*7,000*	*5,700*					—		
IV. BULKLEY													
1. *Morice Lake*													
Nanika River	—	65,000	—	—	—	—	10.0	15	20	53.		Very restricted and concentrated in patches	Fast flowing rivers, heavy silt and falls
Morice River	—	5,000	—	—	—	—	4.0	35	5	12.			
Gosnell Creek	—	100	—	—	—	—	0.5	6	10	.5			
Total	*70,000*	*70,000*	*75,000*	*65,000*	*70,000*	*70,000*				*65.5*	1.9		
2. *Bulkley Lake*													
Maxam Creek	—	—	—	—	—	—	—	—	—	—		Unsuitable	Log jams and slow, reduced flow
Total	*500*	*1,000*	*500*	*500*	*800*	*660*					—		

districts. Mr. D. R. Foskett pioneered the Babine district and later, with Mr. P. Abear, moved to the tributaries of the Upper Skeena. Messrs. F. C. Withler and V. H. McMahon, assisted by R. H. Eaton, D. F. Alderdice, W. R. Hourston and M. P. Shepard, carried the load of the Babine district in later years. The Morice Lake assessments have been made mainly from observations at Moricetown Falls where Dr. D. J. Milne has been in charge, assisted by Messrs. H. Godfrey and E. W. Burridge. Much of the basic work of the Lower Skeena was shouldered by Mr. J. A. McConnell supported by Messrs. D. Fisher, A. C. Johnson and D. K. Foerster. Throughout these expeditions and taking part in some, Dr. R. E. Foerster, Director of the Pacific Biological Station, has continued to offer his assistance.

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REFERENCES

ANONYMOUS. Pacific drainage. *Water Resources Paper*, No. 94. Dominion Water and Power Bureau, 1946.

ANONYMOUS. Interim report on the Chilko River watershed. 70 pp. Int. Pacific Salmon Fish. Comm., 1949.

BRETT, J. R. A study of the Skeena River climatological conditions with particular reference to their significance in sockeye production. *J. Fish. Res. Bd. Can.*, **8**, 178-187, 1950a.

The physical limnology of Lakelse Lake, British Columbia. *J. Fish. Res. Bd. Can.*, **8**, 82-102, 1950b.

MILNE, D. J. Salmon tagging off the Skeena River in 1948. *Fish. Res. Bd. Can., Prog. Rept. Pacific*, No. 80, 50-51, 1949.

PRITCHARD, A. L. Sockeye salmon tagging off the Skeena River in 1944. *Fish. Res. Bd. Can., Prog. Rept. Pacific*, No. 61, 8-12, 1944.

Sockeye salmon tagging off the Skeena River in 1945. *Ibid.*, No. 65, 77-79, 1945.

Sockeye salmon tagging off the Skeena River in 1946. *Ibid.*, No. 70, 13-16, 1947a.

Fish cultural problems involved in the conservation of anadromous fish, with particular reference to salmon on the Skeena River, British Columbia. *Can. Fish Culturist*, **1**(2), 8-14, 1947b.

Sockeye salmon tagging off the Skeena River in 1947. *Fish. Res. Bd. Can., Prog. Rept. Pacific*, No. 75, 40-42, 1948.

PRITCHARD, A. L., AND J. R. BRETT. A sockeye salmon tagging experiment at Lakelse Lake. *Fish. Res. Bd. Can., Prog. Rept. Pacific*, No. 62, 4-7, 1945.

PRITCHARD, A. L., AND W. M. CAMERON. Observations on the sockeye run at Lakelse Lake (Skeena River) in the year 1939. *Fish. Res. Bd. Can., Prog. Rept. Pacific*, No. 43, 14-16, 1940.

WITHLER, F. C., J. A. MCCONNELL AND W. H. MCMAHON. Lakes of the Skeena River drainage. IX. Babine Lake. *Fish Res. Bd. Can., Prog. Rept. Pacific*, No. 78, pp. 6-11, 1949.

Growth and Triaenophorus Parasitism in Relation to Taxonomy of Lake Winnipeg Ciscoes (Leucichthys)[1]

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ABSTRACT

Four species of Lake Winnipeg ciscoes (*Leucichthys*, Coregonidae) were found to differ in several biological characteristics thus supporting their validity as species. *L. nigripinnis* and *tullibee* attained a larger size than either *nipigon* or *zenithicus*. The curves of growth differed for the four species. *L. nipigon* had a higher incidence of infection by the pseudophyllidean tapeworn, *Triaenophorus crassus*, than did the other three species. There was no evidence of common relationship among three species between infection and age of host.

INTRODUCTION

Morphological criteria have been used heretofore in developing the present conception of *Leucichthys* (Coregonidae) systematics but a wider range of biological information seems applicable. The problem considered is whether maximum size, curve of growth, and parasitic infection support the existing taxonomy of the Lake Winnipeg ciscoes.

MATERIALS AND METHODS

Since the various species of ciscoes were indistinguishable to the author in the field, identifications were made in the laboratory from the collected data. The keys used for identification may be found in Dymond and Pritchard (1930) and Dymond (1947).

Data from 887 specimens comprising 504 *L. zenithicus*, 164 *L. nigripinnis*, 181 *L. nipigon*, and 38 *L. tullibee* were used in this paper. These ciscoes were taken in gill nets between June, 1947, and August, 1949. Seventy-five per cent of the specimens were collected off Mukatawa River; the remainder were taken at Black Bear Island, Matheson Island, and Gimli.

Age determinations were made by the scale method. Scales were obtained from the region of the fish between the dorsal fin and the lateral line. Before reading, the individual scales were cleaned by immersing them for 10 to 20 minutes in a 5 per cent solution of "Javex". (Dr. W. B. Scott of the Royal Ontario Museum of Zoology made this suggestion.) Three or four scales were mounted "wet" between microscope slides and magnified by a Bausch and Lomb microprojector. Magnification used was 26 times. One hundred and fifty scales were examined twice to determine the degree of accuracy in reading the age of any one fish. Sixty per cent of the age determinations were identical. Thirty and ten per cent respectively showed one and two years disagreement. After this preliminary test all the scale samples were read once and a definite age was assigned. At no time was reference made to the species, length, or weight of the specimens.

[1]This paper is based on a thesis submitted in partial fulfilment of the requirements for the degree of Master of Arts at the University of Toronto.

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Ages were recorded as the number of completed years. Fish captured in the summer of 1947 whose scales revealed two annuli were regarded as two years old and as members of the 1945 year class.

The standard length records the size of the specimens. This is the length in millimeters of the antero-posterior axis measuring from the tip of the snout to the beginning of the upturned end of the vertebral column.

Examination for *Triaenophorus* cysts was done in the same manner as in the Federal Department of Fisheries inspection. The fish were filleted by cutting both sides of the body away from the vertebral column. The ribs were then removed. Each fillet was systematically cut into small pieces of one-quarter inch thickness. The number of cysts seen during these operations was recorded.

RESULTS

Maximum Size

The ciscoes were arranged into length frequency distributions (Table I) to demonstrate any possible differences in size. The smallest specimen was 105 mm. in length (*L. zenithicus*); the largest 353 mm. (*L. tullibee*). Although the upper range limit of the four species is similar, the percentage of specimens attaining a standard length of 300 mm. differs among species. The percentages are: *tullibee*, 26; *nigripinnis*, 22; *nipigon*, 2; *zenithicus*, 1.

Table I. Length-frequency distribution of *Leucichthys* collected from Lake Winnipeg, 1947-49.

Standard length in mm.	*zenithicus*	*nigripinnis*	*nipigon*	*tullibee*
100–119	17	1	—	—
120–139	34	12	—	—
140–159	14	12	—	—
160–179	18	3	—	1
180–199	34	19	1	1
200–219	46	14	4	1
220–239	141	22	20	6
240–259	145	19	68	7
260–279	50	12	70	9
280–299	2	16	14	6
300–319	2	18	3	3
320–339	—	12	1	3
340–359	1	4	—	1
360–379	—	—	—	—
Totals	504	164	181	38

Koelz (1929) noted that *zenithicus* in both Lakes Superior and Huron rarely exceeded a length of 300 mm. A frequency distribution in Van Oosten's study (1937) of Koelz's Lake Superior specimens revealed that only four of the 859 specimens were 300 mm. and over. Dymond (1926) did not present the size range of *zenithicus* found in Lake Nipigon. He implied that they were generally under 300 mm.

Although there has been no detailed account published of the size attained by *nigripinnis*, Koelz's monograph (1929) substantiates these findings that it reaches a large size. Dymond and Pritchard (1930) listed a mean length of 294 mm. for five *nigripinnis* from Lake Winnipeg.

GROWTH

The growth exhibited by a species is seldom uniform. Differential growth among year classes and localities and between the sexes may occur. Paucity of material prevented statistical analysis as to the significance of the variation attributed to the first two conditions. The differences in average size of males and females of the same age and species were tested by the "*t*" test. Of 17 comparisons only three were significant (P value between .05 and .01). These were *nigripinnis* five-year-olds, *nigripinnis* seven-year-olds, and *nipigon* six-year-olds. With regard to *nigripinnis*, at age 5 the females were larger while at age 7 the males were larger. On the basis of the above information, it was decided that the growth data for the sexes could be combined.

Table II presents length frequency distributions, grouped according to age, for *zenithicus*, *nigripinnis* and *nipigon* collected at all localities during the three years on Lake Winnipeg.

This table illustrates the age composition of the samples. For all species the majority of the fish were four to seven years old. The oldest individual was a *nigripinnis* in its twelfth year. Kennedy (1949) found *L. artedi* in Great Bear Lake to attain 13 years. No young of the year or yearlings of *Leucichthys* were collected. Even the two-year-old fish were not well represented; 13 in all having been taken. Twelve of these fish were *zenithicus*. The youngest *nipigon* collected was four years old.

The absence of the two- and three-year-olds of this species, when these same age groups were represented in the *nigripinnis* and *zenithicus* samples, could not be explained. From an examination of the growth curves (Figure 1) young *nipigon* would be expected to be larger than young *nigripinnis* and *zenithicus* so they could have been taken by the fishing gear. Possibly they live in other areas or depths than those sampled. Dymond (personal communication) did not collect any *nipigon* under 175 mm. during the Lake Nipigon investigation, 1921-24.

Leucichthys vary in length within age groups. This variation is undoubtedly exaggerated because fish were taken at various times during their growing season. In age groups 4 to 7 the range in length within an age group approximates 140 mm.

Curves of growth for Lake Winnipeg *Leucichthys* are shown in Figure 1. To ascertain the extent to which the curves can be considered the same, a modified "*t*" test (Snedecor, 1946, p. 83) was used. This tested the differences between species in average standard length of each age group. In four comparisons *zenithicus* was found to have a significantly different mean value from *nipigon*. Thus, for the ages tested, the growth curves of these species are considered dissimilar. In four tests between *nipigon* and *nigripinnis*, at age 6 only was the

Table II. Relationship between age and length in Lake Winnipeg *Leucichthys* collected 1947-49. Age is recorded in completed years and standard lengths are in millimeters.

Midpoints of class interval	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	260	270	280	290	300	310	320	330	340	350	Totals	Mean	S.E. Mean
Age 2																												
zenithicus	—	6	2	1	—	1	1	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	12	138	8.86
nigripinnis	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1		
Age 3																												
zenithicus	2	10	12	8	2	2	1	1	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	40	135	3.33
nigripinnis	—	2	4	4	2	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	14	138	3.58
Age 4																												
zenithicus	—	2	7	3	3	2	7	1	8	6	5	3	5	2	1	1	—	—	—	—	—	—	—	—	—	56	182	4.90
nigripinnis	—	—	2	3	3	2	1	2	5	5	2	1	2	1	—	—	1	—	—	—	—	—	—	—	—	30	183	6.61
nipigon	—	—	—	—	—	—	—	—	—	—	2	3	2	4	—	—	1	—	—	—	—	—	—	—	—	12	230	4.94
Age 5																												
zenithicus	1	—	—	1	2	1	3	4	3	13	8	30	30	28	13	3	1	—	—	—	—	—	—	—	—	141	221	2.08
nigripinnis	—	—	—	1	—	—	—	2	3	7	3	3	6	3	6	2	1	4	—	—	—	—	—	—	—	41	225	5.21
nipigon	—	—	—	—	—	—	—	—	—	1	—	2	3	12	17	14	8	4	—	—	1	—	—	—	—	62	252	2.10
Age 6																												
zenithicus	—	—	—	—	—	—	—	1	2	2	5	16	22	36	29	24	8	—	—	—	—	—	—	—	—	145	240	1.45
nigripinnis	—	—	—	—	—	—	—	—	—	3	1	1	3	7	3	1	3	2	1	4	3	—	—	—	—	32	256	6.02
nipigon	—	—	—	—	—	—	—	—	—	—	—	1	—	5	14	13	11	10	—	2	1	—	—	—	—	57	262	2.10
Age 7																												
zenithicus	—	—	—	—	—	—	—	1	—	—	2	2	12	10	21	22	11	2	2	1	—	—	—	—	—	86	250	1.96
nigripinnis	—	—	—	—	—	—	—	—	—	—	—	—	—	1	3	—	2	1	3	1	—	3	2	—	—	16	287	7.69
nipigon	—	—	—	—	—	—	—	—	—	1	—	—	—	—	5	10	14	8	3	—	—	—	1	—	—	42	267	2.68
Age 8																												
zenithicus	—	—	—	—	—	—	—	—	—	—	—	1	—	1	7	3	3	2	—	—	1	—	—	—	—	18	258	4.38
nigripinnis	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	1	1	5	5	1	1	1	16	313	4.95
nipigon	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	1	—	—	—	—	—	—	3		
Age 9																												
zenithicus	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	1	—	—	—	—	—	1	—	3		
nigripinnis	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	1	2	1	—	2	2	1	11	313	7.37
nipigon	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	1		
Age 10																												
zenithicus	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	1		
nigripinnis	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	1	2		
Age 11																												
nigripinnis	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	1		

difference of means not statistically significant. Comparison of the *zenithicus* and *nigripinnis* samples showed that at ages 3, 4, and 5 the means were not significantly different but from age 6 onwards they differed significantly.

The growth curves of *zenithicus* and *nigripinnis* are considered identical from the second to the fifth year. From that time on they diverge in size because *zenithicus* has reached its upper asymptote of growth. Indications are that the decline in the growth rate of *nigripinnis* commences at eight years. Initially *nipigon* must grow faster than *zenithicus* or *nigripinnis* in order to be the largest at four years of age. It averages longer than either species also at five and six years of age. However, *nipigon* does not maintain this lead but is succeeded by *nigripinnis* after the sixth year. The eventual "final" size of *nipigon* is intermediate between *nigripinnis* and *zenithicus*.

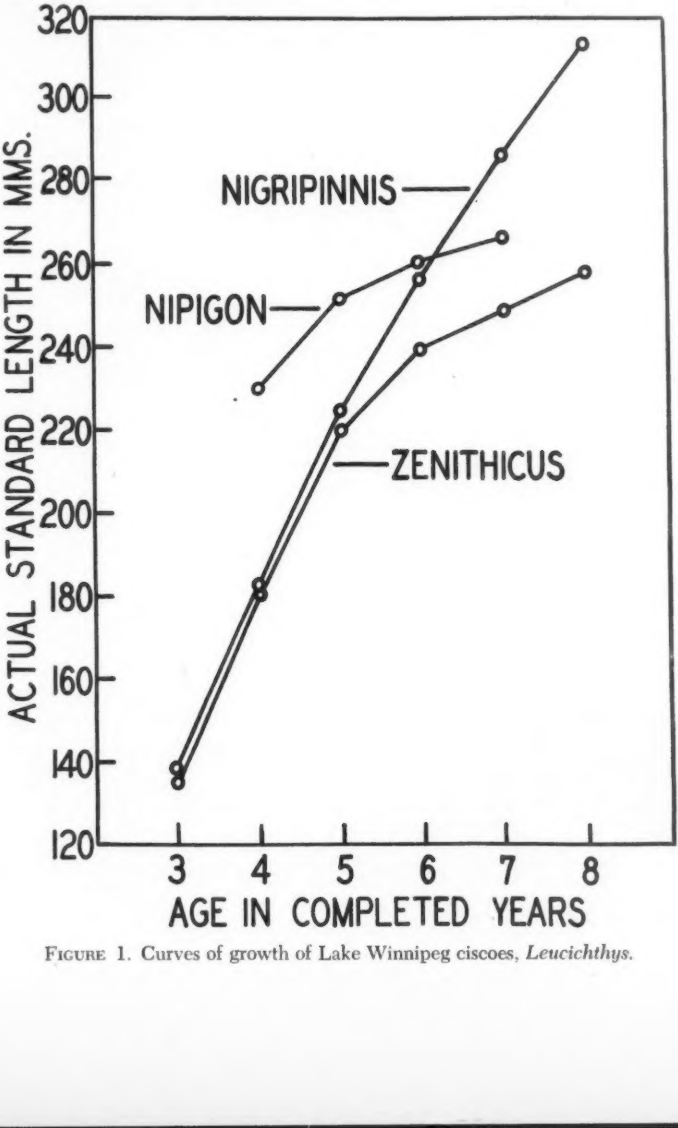

FIGURE 1. Curves of growth of Lake Winnipeg ciscoes, *Leucichthys*.

Owing to the small numbers of *tullibee* collected, no growth curve has been presented. The limited data suggest that it is similar to *nipigon* at ages 4 and 5 but more closely resembles *nigripinnis* than the other species at ages 7 and 8.

INFECTION

INCIDENCE. *Triaenophorus crassus* is a pseudophyllidean tapeworm completing its life cycle in freshwater teleost fish and copepod crustacea. With respect to the second intermediate host, Miller (1945) observed some degree of specificity. Where whitefish (*Coregonus clupeaformis*) and ciscoes (*Leucichthys* spp.) occurred together in infected lakes, Miller stated that the latter were more heavily parasitized. Other fish in which the occurrence of cysts has been recorded are round whitefish (*Prosopium* spp.), lake trout (*Cristivomer namaycush*), inconnu (*Stenodus leucichthys*) and northern pike (*Esox lucius*). Little consideration has been given to differential infection among species of ciscoes. Newton (1932) determined, for *Leucichthys zenithicus* and *L. tullibee* in Lake Winnipeg, percentages of infected fish and number of parasites in each individual.

The purpose of recording *T. crassus* plerocercoid infection of the Lake Winnipeg ciscoes was to determine if the incidence of infection differed among the four species. Difficulties hindering the solution of the problem soon appeared. Infection rates are influenced by the age of the host (Miller, 1945, 1948; Oakland, 1949). The infection rate also varies from year to year in the same locality and in different localities in the same year (Oakland, *ibid.*). Initially it was believed that the infection data could be analysed for these effects by means of analysis of variance. Examination of the data when arranged in analysis of variance tables revealed that the subclass numbers were "disproportionate" (Snedecor, 1946, p. 284). The statistical analysis would necessarily be complicated. Furthermore, examination of frequency polygon graphs revealed that the occurrence of cysts per fish, in *zenithicus* and *nigripinnis*, follows a Poisson-type distribution. Newton (1932) presented a graph showing similar skewed distributions for infection of three Lake Winnipeg coregonines. In these types of distribution the variance is not independent of the mean. Unless a suitable transformation of the variates is utilized, tests of significance by analysis of variance are not strictly allowable. For these reasons the effects of year classes, age, and locality had to be disregarded when considering infection differences among species.

Table III presents the infection data. Line two of this table shows that *zenithicus, nigripinnis, tullibee* and *nipigon* were 62, 61, 58, and 96 per cent infected, respectively. To determine if the proportion of clear to infected fish was the same in the various species, "2 $\times$ C" tables were used. The homogeneity test when the four species were considered resulted in a rejection of the null hypothesis (P value less than .01). The value of chi-square which was obtained in a second test involving *zenithicus, nigripinnis* and *tullibee* was not significant. It was concluded that the percentage infection differed between *nipigon* and each of the other three species. *L. zenithicus, nigripinnis* and *tullibee* were considered to be infected to the same degree.

Line three of Table III records the mean number of cysts per fish. Infection, as judged from these mean values, is highest in *nipigon* and is considered to be different from that in the other three species. It might be suggested that the postulated differences in infection between *nipigon* and the other species is consequent upon the low number of non-parasitized *nipigon* in contrast to the greater percentages of clear *zenithicus*, *nigripinnis*, and *tullibee*. This is undoubtedly true in part but inspection of the mean cyst counts for infected fish only (line 4) shows that the relative position of the means does not change.

TABLE III. *Triaenophorus* infection of *Leucichthys* collected from Lake Winnipeg, 1947-49.

	zenithicus	*nigripinnis*	*nipigon*	*tullibee*
No. of specimens	501	164	176	38
Percentage infected	62	61	96	58
No. of cysts per fish	1.5	2.4	7.1	1.4
No. of cysts per infected fish	2.5	3.8	7.5	2.5

Newton (1932, p. 347) presented data on infection of *zenithicus* in Lake Winnipeg. His figures when recombined compare favourably with the author's data given in Table III. Newton's data, based on 4,149 fish, showed 60 per cent of the individuals infected, whereas 62 per cent of the 1947-49 *zenithicus* specimens were parasitized. The mean number of cysts per fish for Newton's specimens was 1.4; for infected fish only, the average was 2.4. Between these figures and the author's, there is only 0.1 difference in each case.

INFECTION AND AGE OF HOST. Miller (1945, 1948) found in Lesser Slave Lake that plerocercoid infection was positively correlated with the age of the host. This was more evident in the ciscoes which Miller believed to be *Leucichthys tullibee*. He stated that "the number of plerocercoids per fish increases with the age of the fish up to five or six years".

TABLE IV. Mean *Triaenophorus crassus* infection with age of *Leucichthys*. Specimens from Mukatawa River, 1947-49. Figures in parentheses are number of specimens.

Age in completed years	3	4	5	6	7	8	9+
zenithicus							
1947	1.6(20)	1.4(31)	1.5(71)	1.2(73)	1.3(54)	1.5(10)	0.0(1)
1948	3.3(3)	1.3(6)	1.3(32)	1.6(47)	1.6(25)	5.0(1)	1.0(1)
1949	2.0(10)	2.0(7)	3.0(11)	2.2(8)	0.0(1)	1.0(2)	—
nigripinnis							
1947	2.0(3)	3.8(7)	2.8(20)	3.4(21)	1.8(13)	0.9(16)	0.9(11)
1948	1.0(1)	0.0(1)	4.2(5)	6.6(3)	11.0(1)	—	0.0(1)
1949	3.3(4)	4.0(3)	0.6(3)	8.0(2)	3.0(1)	—	1.0(1)
nipigon							
1947	—	3.2(7)	5.3(25)	8.3(38)	8.3(28)	14.3(3)	11.0(1)
1948	—	5.2(2)	6.3(29)	6.7(16)	8.0(10)	—	—
1949	—	4.0(1)	10.0(1)	—	—	—	—

It is interesting to determine if the same relationship applies to the Lake Winnipeg ciscoes. Unfortunately only 38 *tullibee* were collected, therefore, a reinvestigation of his conclusions with reference to that species was not possible. For the other three species the mean cyst count for each age group collected at the Mukatawa River locality is recorded in Table IV. Owing to the nature of the frequency distributions, the standard error of the means was not calculated and consequently, the differences of the means within and between species were not tested.

Not all the species of Lake Winnipeg ciscoes show an increase in infection with age. It is present in *nipigon* but not *zenithicus*. The mean cyst count of *zenithicus* shows no correlation with age, the mean cyst count of the 1947 specimens fluctuates between 1.2 and 1.6 cysts per fish. In the 1947 *nigripinnis* sample there is an increase in mean cyst count from the third to the fourth year, then a fluctuating but gradual decline in cyst count. Although such limited data make any deductions tentative, it is indicated that there is no common relationship between age and infection that is applicable to all species of Lake Winnipeg ciscoes.

DISCUSSION

Twenty years ago Dymond and Pritchard, using limited material, concluded that the Lake Winnipeg ciscoes comprised four species: *L. zenithicus, L. nipigon, L. nigripinnis* and *L. tullibee*. Reinvestigation of these ciscoes was started for two reasons. Examination by the author of the morphometrical characteristics of a large series of specimens revealed them to be so provokingly similar that the discreteness of the species was doubted. As may happen in the case of sympatric groups, it was thought that arbitrary limits might have been placed on one exceedingly variable species. Furthermore, on the basis of investigations of other waters, suspicion has centered on the validity of *nipigon* and *tullibee* in particular.

The taxonomy of the ciscoes has been investigated from a biological viewpoint. Instances may be noted where information from other fields of zoology have been used as an aid in the recognition and definition of taxonomic groups. *Drosophila simulans* was recognized because of its breeding behaviour (Huxley, 1940). Ticehurst found nesting sites to be distinctively different in two morphologically similar species of old world warblers (Mayr, 1942). Kennedy (1943) discovered two "groups" of the whitefish *Coregonus clupeaformis* from the fact that each matured at a different size.

This biological study is concerned with the validity of described species rather than the recognition of new ones. The conclusion is restricted by the following consideration. Characteristics of related species may be studied which have not been recorded as taxonomic characteristics. The validity of two species is not affected by the discovery that characteristics of this nature are identical in both. Differences may enhance but similarities do not necessarily destroy the reality of taxonomic distinction.

Although it is not known whether the biological differences found among the four *Leucichthys* species are expressions of the genotype, the environment, or the product of both, they reveal discontinuities which parallel morphological

and morphometrical characteristics. Support for the original designation is afforded when groups which were assigned specific status by reason of morphological distinctiveness reveal also biological differences. It is in this correlation between biological and morphological characteristics that the present study corroborates Dymond and Pritchard's opinion that *L. zenithicus, L. nigripinnis, L. nipigon,* and *L. tullibee* occur in Lake Winnipeg.

RECOMMENDATION

The discovery that incidence of infection and relationship between age and infection differ among species of Lake Winnipeg *Leucichthys* prompts the suggestion that identification of ciscoes be made whenever this group is investigated with reference to *Triaenophorus crassus.*

SUMMARY

The ciscoes of Lake Winnipeg, Manitoba, have been studied with respect to maximum size attained, curves of growth, and infection by the tapeworm *Triaenophorus crassus.* The 887 ciscoes collected from 1947 to 1949 were found to comprise 504 *Leucichthys zenithicus,* 164 *L. nigripinnis,* 181 *L. nipigon* and 38 *L. tullibee.*

L. nigripinnis and *L. tullibee* were found to attain the largest size. For the ages observed the differences in length between the sexes were found to be negligible in three species examined. The range in length of a cisco of a given age was approximately 140 mm. The growth curve of *nipigon* differs from those of *zenithicus* and *nigripinnis.* In the latter two species the curves are not considered different from the second to the fifth year but differ from ages 6 to 8. The curve of growth of *tullibee* was not calculated.

The incidence of the pleroceroid stage of *T. crassus* in the four species was considered. Although such factors as the age of the fish, year and place of capture have been shown to influence the infection rate it was not possible to allow for these effects in the present study. Percentages of specimens infected and the mean number of cysts per fish have been the measures of infection. It was concluded that there were no differences in infection rates among *tullibee, zenithicus* and *nigripinnis,* and that these three all differed from *nipigon.* There appeared to be no common relationship between infection and age of host in three species examined.

The present study has shown that the ciscoes of Lake Winnipeg, which were identified on the basis of morphological and morphometrical characteristics differ in several biological characteristics. It is concluded that this parallelism between morphological and biological characteristics supports the opinion that four species of ciscoes occur in Lake Winnipeg.

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REFERENCES

Dymond, J. R. *Univ. Toronto Stud., Biol. Ser.*, No. 27; *Publ. Ontario Fish. Res. Lab.*, No. 27, 1926.

Roy. Ontario Mus. Zool., Misc. Publ., No. 1, Toronto, 1947.

Dymond, J. R. and A. L. Pritchard. *Contr. Can. Biol. and Fish.*, **5** (1929), 1930.

Huxley, J. Towards the new systematics. *In* The New Systematics, ed. by J. Huxley, pp. 1-46. Oxford, 1940.

Kennedy, W. A. *Univ. Toronto Stud., Biol. Ser.*, No. 51; *Publ. Ontario Fish. Res. Lab.*, No. 62, 1943.

Bull. Fish. Res. Bd. Can., No. 82, 1949.

Koelz, W. *Occ. Papers Mus. Zool., Univ. Michigan*, No. 158, 1925.

Bull. U.S. Bur. Fish., No. 43 (1927), 1929.

Mayr, E. Systematics and the origin of species. New York: Columbia University Press, 1942.

Miller, R. B. *Can. Jour. Res.*, D, **23**, 1945.

Can. Jour. Res., D, **26**, 1948.

Newton, M. V. B. *Contr. Can. Biol. and Fish.*, **7**, 1932.

Oakland, G. B. *Central Fish. Res. Sta., Ann. Rept. for 1949*, App. 9. Fish. Res. Bd. Canada, 1949 (mimeographed).

Snedecor, G. W. Statistical methods. Iowa State College Press, 1946.

Van Oosten, J. *Papers Michigan Acad. Sci., Arts and Letters*, **22** (1936), 1937.

The Effects of Tagging upon a Pacific Coast Flounder, Parophrys vetulus

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ABSTRACT

Controlled experiments carried out over a three month period on lemon sole (*Parophrys vetulus*) show that tagging, using the Petersen type of tag, causes significantly more deaths among females than would normally occur, and it is suggested that this is true also for males. The rate of tagging mortality without competition from other types of mortality, extrapolated over a period of one year, was computed to be 41 and 49 per cent for males and females respectively. In neither sex did fish of different sizes die differentially as regards either the number of deaths or the rate at which they occurred. By affixing tags according to three degrees of looseness (0.76 mm., 1.52 mm., and 2.28 mm.) and to different positions on the fish (the nape, below the dorsal fin at the widest dorso-ventral position, and on the caudal peduncle) it was shown that the loosest attachment, and application below the dorsal fin, caused least injury to the fish, as well as the least number of deaths.

INTRODUCTION

Petersen-type tags have been generally used in investigating flatfish life histories without any systematic study of their effects on the fish, or of the most advantageous method of affixing them. This report describes experiments carried out on the lemon sole, *Parophrys vetulus*, to determine the mortality caused by this type of tag, and the best position and tightness to use in applying it.

MATERIALS AND METHODS

Lemon sole were captured by the Pacific Biological Station's research trawler on a fishing ground some ten miles distant from the Station. All drags were limited to 15 minutes in order to minimize any injury which might result from capture. The fish were then transported in live tanks to the Station's retaining tank. Five successive daily trips were required before the operation was completed. Only those fish that appeared to be in good condition were used.

The experiments were carried out between December 1, 1948, and February 28, 1949, in a 20 foot (6.1 m.) by 87 foot (26.5 m.) concrete tank situated in the inter-tidal zone. As far as possible, natural conditions were simulated by covering the rough cement floor with mud in order to eliminate possible mortality caused by abrasion of the fish by the bottom. A supply of fresh sea-water, the volume of which fluctuated between 20,000 gallons (91.4 kl.) and 90,000 gallons (411.4 kl.) was maintained at all times with the changing tides. In spite of this, it is likely that light, temperature, salinity, and pressure were far from being the same as in the fish's normal habitat. Feeding was considered unnecessary since lemon sole do not feed very actively during the winter, their spawning season.

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The tag used consisted of two baffles, each measuring 12 mm. in diameter and 0.5 mm. in thickness. The baffles were affixed, one to each side of the fish, by a corrosion-resistant nickel pin which passed through the body. The pointed end was cut off at a constant distance from the dorsal baffle and the protruding length was rolled so that the same estimated degree of tension was exerted on each fish. When a tag was to be applied with a given degree of looseness, a partially split celluloid plate of that thickness was placed between the fish and the baffle on the dorsal or eyed side. After the tag was affixed, the plate was easily removed by sliding it out from under the tag.

MORTALITY AMONG FISH OF DIFFERENT SIZE. To determine whether differences in mortality exist between fish of different sizes, both sexes were divided into size-groups. For males the size-groups were 25–27 cm., 28–30 cm., 31–33 cm., and 34–36 cm.; and for females 31–33 cm., 34–36 cm., 37–39 cm., 40–42 cm., and 43 cm. or larger. Commencing with the first fish in each size group, alternate fish were tagged.

COMPARISON OF TAGGING TECHNIQUES. To compare tagging techniques only male fish of the 34–36 cm. size-group were used. This group was selected since it was felt that it would best represent in size the mid-point of the range in length

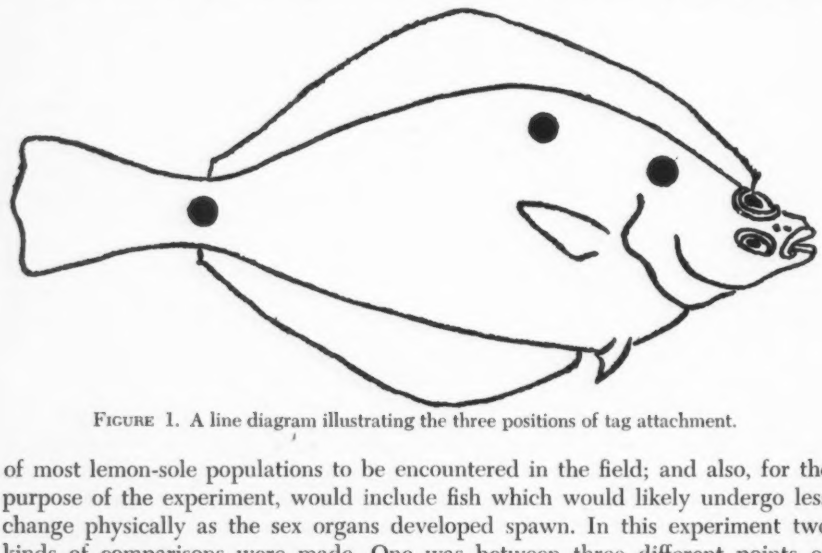

FIGURE 1. A line diagram illustrating the three positions of tag attachment.

of most lemon-sole populations to be encountered in the field; and also, for the purpose of the experiment, would include fish which would likely undergo less change physically as the sex organs developed spawn. In this experiment two kinds of comparisons were made. One was between three different points of attachment; namely the nape, below the dorsal fin at the widest dorso-ventral position, and on the caudal peduncle (Figure 1). The tags used here were applied as they had been previously in the field; that is, with the baffles close to the skin, but not tightened so as to press into it. The second comparison was between tags applied with different degrees of looseness; namely clearances of 0.76 mm., 1.52 mm., and 2.28 mm. Fish for each of the six tagging procedures were taken in

rotation; that is, every sixth fish received the same treatment. The survival of these was compared with the untagged 34–36 cm. group of the experiment on mortality.

Twenty fish were used in each experimental and control group, making a total of 480 fish in all. The sex of each fish could be determined by inspection at the time of tagging.

At first, observations were carried out daily; later, on alternate days. To facilitate the recovery of dead fish the tank was partially drained and the bottom was inspected through a partially submerged glass bottom box which was fastened to the stern of a skiff. In the laboratory, the dead fish were examined and the tagged ones identified according to experiment by the numbered baffle of each tag. The controls were assigned to proper size-groups simply by measuring them, since growth was considered to be negligible during the period of the experiment.

Upon termination of the experiment the tank was completely drained and all but 19 fish could be accounted for. Of the missing fish, 16 belonged to the experiment on mortality of different size-groups.

DIFFERENTIAL MORTALITY

In Table I is given the number of fish of each sex and size-group that died

TABLE I. The number of dead fish occurring in the different size-groups of twenty fish each, and the calculated instantaneous and annual rates of mortality.

Size-group (cm.)	Male		Female	
	Tagged	Control	Tagged	Control
25–27	3	1	—	—
28–30	4	0	—	—
31–33	3	0	8	2
34–36	4	4	6	2
37–39	—	—	1	1
40–42	—	—	5	1
43+	—	—	3	3
Total	14	5	23	9
Percentage	17.5	6.3	23.0	9.0
Inst. mort. (per annum)	0.76	0.21	1.04	0.36
Ann. mort. (%)	53.2	21.3	64.6	30.2

during the experiment on mortality. The total number of deaths, as a fraction of the initial number, constitutes a "seasonal" mortality rate (Ricker, 1944). By converting these seasonal values to an exponential function a corresponding "instantaneous" rate is obtained. That this instantaneous rate is a reasonable reflection of a physical reality is shown by the fact, discussed later, that a rather uniform fraction of the fish died through the course of the experiment. Unfortunately there is no direct evidence that this situation would have persisted for a longer period of time. However, mortality in fishes is almost always computed on a yearly basis, because estimates of total mortality can ordinarily be computed at

no shorter interval. So that this work may be directly comparable, the quarterly instantaneous rates are multiplied by four to obtain the estimated instantaneous rate for a year's time, and from these the corresponding annual mortality is computed. These are also shown in Table I. Assuming that the mortality rate in the controls represent "normal" mortality, the difference in mortality between tagged and control fish can be ascribed to tagging. The difference, which is the estimate of excess mortality for a year, was found to be 31.9 and 34.4 per cent for males and females respectively.

To ascertain the significance of tagging as a factor in mortality the data in Table I for tagged and control fish were compared, for both males and females. A comparison was also made between the tagged fish of both sexes, as well as between all the size-groups for the tagged and control fish. Chi-square values for these comparisons, corrected for continuity wherever possible, have been calculated and are presented in Table II along with the corresponding level of probability. It can be seen that tagging imposes a significant additional mortality upon females, and it is suggested that this is true also for males (94 per cent confidence).

TABLE II. Chi-square values for various comparisons, corrected for continuity wherever possible, and the corresponding P levels for the respective degrees of freedom (n).

Comparison	χ^2	n	P
Mortality between males, tagged and control	3.82	1	.10–.05
Mortality between females, tagged and control	6.29	1	.02–.01
Mortality between males and females, tagged	1.26	1	.30–.20
Mortality between tagged and control males of different size-groups	4.95	3	.20–.10
Mortality between tagged and control females of different size-groups	4.93	4	.30–.20

Between tagged males and females, and among all size-groups of the tagged and control fish of each sex, there is little suggestion of any difference in mortality. No attempt was made to compare the data for size-groups which were common to both sexes since the fish in them are of different ages and would, therefore, have different natural mortality rates.

A comparison has been made of the viability of the various size-groups by estimating the mean survival period of each. Of the 51 fish that died, the date of death of 30 was known. Five fish were picked up in different stages of decomposition, and a guess was made of the length of time each had been dead. This period never exceeded two weeks. The remaining 16 fish (5 tagged males, 8 tagged females, and 3 control males) were never recovered. The date of death of each of these was taken as half the mean duration of the experiment for the group to which it belonged, because the distribution of known dates of death was approximately uniform for the whole duration of the experiment. Since the unrecovered fish are distributed rather equally among all the size-groups (except the female 31–33 cm. group, (in which there were 5 missing tagged fish and 2 missing controls), the mean survival period of each group is liable to error by approximately the same amount. Further, because the completion of some groups required more time than others, the maximum mean survival period is not the

TABLE III. The mean survival period, weighted up to 90 days, of male and female tagged and control fish of different size-groups.

Size-group (cm.)	Mean survival period MALE Tagged	Control	Difference	FEMALE Tagged	Control	Difference
25–27	84.9	89.9	5.0	—	—	—
28–30	82.7	90.0	7.3	—	—	—
31–33	85.5	90.0	4.5	73.2	85.5	12.3
34–36	84.0	79.9	−4.1	82.7	89.3	6.6
37–39	—	—	—	88.9	89.2	0.3
40–42	—	—	—	82.6	89.7	7.1
43+	—	—	—	85.3	85.5	0.2
Grand mean survival period	84.3	87.5	3.2	82.5	87.8	5.3

same for all groups. To compensate for the slight difference (the greatest being 2.6 days) all survival periods were weighted up to the maximum period, 90 days. As shown in Table III, tagged fish in all size-groups but the male 34–36 cm. group have a shorter survival period than do the untagged fish. Although none of the individual differences between tagged and controls is significant, the fact that eight out of nine are in the same direction indicates with 96 per cent confidence that tagging does decrease survival. There is little indication that survival is correlated with the size of the fish.

TAGGING TECHNIQUE

The number of deaths occurring in the groups of fish subjected to various tagging treatments is shown in Table IV. No one technique caused significantly more deaths than another but some are to be favoured for other reasons. On some fish tagged through the caudal peduncle extensive irritation was observed in that region, and in one instance the tail had been lost, the tag being insecurely held by skin and bones. Such extensive lesions may have been responsible for the greater number of deaths in this group. Lesions as great as these were never noted on fish tagged through the nape or below the dorsal fin.

Among fish with tags applied with different degrees of looseness, no group having a given looseness differed in mortality from the others to a degree which could not have occurred by chance alone; however, the fewest deaths occurred

TABLE IV. Number of dead fish in the groups testing different tagging techniques.

Location of tag	Dead	Degree of looseness of tag (mm.)	Dead
Nape	4	0.76	1
Dorsal	4	1.52	3
Caudal peduncle	6	2.28	0

TABLE V. Mean measurement of wounds caused by tags applied according to different degrees of looseness, F values (for $n_1=2$, $n_2=54$) determining significance of same, and the percentage of the fish not irritated. (Non-irritated fish are included in determining mean size of wounds.)

Wound description	Degree of looseness (mm.) 0.76	1.52	2.28	F * (calc.)	P
EW	6.3	4.6	2.3	1.99	0.13
ED	1.9	0.2	0.1	2.94	0.060
BW	4.8	4.9	2.6	0.74	>0.20
BD	0.3	0.2	0.1	2.57	0.085
Percentage not irritated	30.0	40.0	60.0		

with the loosest attachment, and in the nape or dorsal position. For all fish the widths and depths of the wounds on the eyed and blind sides were measured to the nearest 0.5 mm. For each measurement the variance of the values obtained for the three degrees of looseness was analysed (Table V). In all four measurements—eyed width (EW), eyed depth (ED), blind width (BW), and blind depth (BD)—the loosest attachment caused least damage, and in three of four the tightest caused most damage. These effects are not statistically significant when considered individually; but if the probabilities for ED and BD are combined by the method of Fisher (1932, sect. 21.1), $\chi^2 = 10.58$ with 4 degrees of freedom, which suggests 97.5 per cent confidence in the reality of the differences in *depth* of wound, the loosest application being the best. In addition to causing least damage, the practice of applying tags loosely allows for growth in thickness in smaller fish.

DISCUSSION

The experiments show that tagging causes mortality in female lemon sole beyond normal expectation, and it is suggested that this is also true for males. Other tests of significance have shown that tagging does not, in either sex, affect the mortality in fish of different sizes differentially, as regards either the number of deaths or the rate at which they occur. It also has been shown that the techniques of affixing the tag loosely, and below the dorsal fin, are to be regarded as less harmful procedures than others tested, and therefore should be used if best results from tagging experiments are to be achieved.

When interpreting these data it should be realized that different strains are placed upon fish in confinement and fish in nature. Fish in confinement are limited in activity and also protected against predators; this possibility favouring the tagged individuals more than the untagged. Confinement, on the other hand, may have had adverse effects, causing disease in some fish and ruptures in a few females that may have made unsuccessful attempts to spawn.

In these experiments every reasonable attempt was made to ensure that differences between experimental and field tagging conditions should be minimal. Accordingly, and in the absence of better data, the results are regarded as useful

in estimating the number of tagged fish in various field experiments that should be available for recapture. For purposes of practical application the number of tagged male and female fish can be expected to be reduced quarterly by instantaneous rates of 0.13 and 0.17 respectively. How far this can be extrapolated to include a whole year's mortality, or even more than a year's, must be decided in each individual case. It can only be pointed out that deaths occurred throughout the whole three months of these experiments, and slightly more frequently towards its close. In the absence of other causes of mortality, the above rate of tagging mortality, extrapolated over a full year, would result in 41 per cent mortality among males and 49 per cent among females. In practice these figures are reduced by the competition of other kinds of mortality.

REFERENCES

FISHER, R. A.. Statistical methods for research workers. London: Oliver and Boyd, 1932.

RICKER, W. E. Further notes on fishing mortality and effort. *Copeia*, **1944** (1), 23-44, 1944.

The Relative Toxicity of Certain Metals to Lobsters

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ABSTRACT

Lobsters held in wooden tanks floored with sheets of copper, monel metal, zinc and lead died within 1, 6, 9 and 20 days respectively. Iron, aluminum and stainless steel were non-toxic.

ALTHOUGH live lobsters are usually held or transported in wooden containers, under some conditions metal or metal-lined containers would offer certain advantages. Since the suitability of various metals for this purpose would involve, among other things, their toxicity to lobsters, an experiment was conducted to determine the relative toxicity of several commonly-used metals.

Seven water-tight tanks, each 4 feet by 4 feet by 8 inches (122 by 122 by 20 cm.) inside dimensions, were constructed of 1¾-inch (4.5 cm.) dressed pine. The floors of six of these tanks were completely covered with sheets of the metals to be tested, the seventh tank serving as a control. Each tank was filled to a depth of 6 inches (15 cm.) with approximately 50 imperial gallons (227 litres) of fresh sea water. This sea water was not replaced during the course of the experiment but on several occasions sea water was added to replace losses from evaporation and leakage. The total amount of sea water added during the experiment did not exceed 45 gallons (204 litres) per tank. Oxygen was supplied by means of compressed air bubbled into each tank through two 24 by 16 mm. cylindrical air breakers at the rate of about one litre per minute. This volume of air was sufficient to maintain the dissolved oxygen above the 75 per cent saturation level. The tanks were placed in an unheated shed and no attempt was made to control temperatures which reached a maximum of 19.9°C. on July 13, 1950, and a minimum of −1.8°C. on December 21, 1950. To delay the accumulation of organic decomposition products the lobsters were not fed throughout the experiment.

Ten vigorous lobsters ranging in total length from 23 to 26 cm. were placed in each tank at 2:00 p.m. on May 23, 1950. Sheets of copper, monel metal, zinc, lead, iron and aluminum were included in the initial test and at 2:00 p.m. on August 22, 1950, stainless steel was added to the series. Observations were made several times a day during the first few days and at daily intervals thereafter. The mortalities observed in each tank to January 2, 1951, when the experiment was terminated, are indicated in Table I.

It is obvious from this table that copper, monel metal, zinc and lead are toxic to lobsters in that order, all of the lobsters dying in the copper-floored tank within 18 hours, in the monel metal within 139 hours, in the zinc within 210 hours and in the lead within 474 hours. The average times to death were 14, 100, 181 and 251 hours at average water temperatures of 11.5, 13.8, 13.9 and 14.3°C respectively.

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TABLE I. Number of lobsters, of a group of 10, which died within the interval shown in the column at left, after being placed in tanks floored with different metals.

Days	Copper	Monel[a] metal	Zinc	Lead	Iron	Aluminum[b]	Stainless[c] steel	Wood (control)
1	10	—	—	—	—	—	—	—
2	—	1	—	—	—	—	—	—
3	—	—	—	—	—	—	—	—
4	—	3	—	—	—	—	—	—
5	—	4	—	—	—	—	—	—
6	—	2	1	1	—	—	1[d]	—
7	—	—	2	—	—	—	—	—
8	—	—	3	—	—	—	—	—
9	—	—	4	1	—	—	—	—
10	—	—	—	—	—	—	—	—
11	—	—	—	1	1	—	—	—
12	—	—	—	—	—	—	—	—
13	—	—	—	3	—	—	—	—
14	—	—	—	—	—	—	—	—
15	—	—	—	—	—	—	—	—
16	—	—	—	—	—	—	—	—
17	—	—	—	1	—	—	—	—
18	—	—	—	—	—	—	1	—
19	—	—	—	2	—	—	—	—
20	—	—	—	1	—	—	—	—
21–40	—	—	—	—	—	—	—	—
41–60	—	—	—	—	—	—	—	1
61–80	—	—	—	—	1	1	1	1
81–100	—	—	—	—	—	—	1	1
101–120	—	—	—	—	—	—	—	1
121–140	—	—	—	—	1	—	1	—
141–160	—	—	—	—	—	3	—	1
161–180	—	—	—	—	3	—	—	1
181–200	—	—	—	—	4	1	—	1
201–220	—	—	—	—	—	1	—	—
221–240	—	—	—	—	—	—	—	—
Total	10	10	10	10	10	6	5	7

a—Ni - 65% to 69%; Cu - 29% to 30%; Fe - 0.9% to 1.5%; Si - 0.25% to 3%; Mn - 0.39% to 1%.
b—Aluminum manganese alloy (AC3S): Mn - 1% to 1.5%; Fe - 0.7%; Si - 0.6%; Cu - 0.2%; Zn - 0.1%.
c—Type 316: Cr - 16% to 18%; Ni - 10% to 14%; Mo - 2% to 3%; Mn - 2%; Si = 1%; C - 0.1%.
d—This lobster was replaced.

The data indicate that iron, stainless steel and aluminum are non-toxic to lobsters, 80 to 100 per cent of the lobsters in these tanks surviving for two months. Deaths in these three tanks after the initial two-month period, which paralleled those in the control tank, were related to moulting, the lobsters either dying in the moulting process or being killed in the soft-shelled condition by other lobsters.

Where metal is required in the holding or transportation of live lobsters the use of aluminum or stainless steel is clearly indicated. Iron, although non-toxic, would not be favoured for such use because of heavy rust formation.

Re-discovery of the Polychaete Worm Trypanosyllis ingens Johnson

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(Received for publication August 23, 1951)

ABSTRACT

Discovery of *Trypanosyllis ingens* Johnson off the west coast of Vancouver island is described. The species has hitherto been known from a single specimen collected at Pacific Grove, California, and described some fifty years ago. It is notable for its large size and the possession of a unique form of prostomium.

The genus *Trypanosyllis* contains the giants amongst the Syllidae. It is distinguished by the dorso-ventrally flattened body, prominent articulated cirri and, in particular, by the pharynx heavily armed with a crown of chitinous teeth (trepan).

Trypanosyllis ingens was described by Johnson (1902) from a single example taken by Dr. Harold Heath at Pacific Grove, California. It is amongst the largest of its genus and differs from all other cogeneric species by the form of its prostomium. It is evidently quite rare. Johnson states "it occurs in none of the numerous gatherings of Pacific coast Polychaeta that came into my hands during six years' residence in California; and Dr. Heath, who has done a great deal of collecting at Pacific Grove and vicinity at all seasons of the year, informs me that he has found only this specimen". Since Johnson's time the Polychaete fauna of the Californian coast (including the type locality of *Trypanosyllis ingens*) has been worked over very extensively, but no second representative of the species has hitherto been found. Its recent appearance off the coast of Vancouver Island seems, therefore, worthy of record, particularly having regard to the rather interesting circumstances of its finding.

In June of 1951 Mr. G. C. Pike of the Pacific Biological Station, observed a large specimen of kelp (*Nereocystis pyrifera*) caught on the fin of a finback whale being towed, via Quatsino Sound, to the whaling station at Coal Harbour on the west coast of Vancouver Island. The stipe of the kelp was some twenty feet long, so that the depth of water in which it had been growing cannot have been more than this. The holdfast was intact and, on removing it from the rock to which it was attached, Mr. Pike found a number of Polychaetes which he kindly handed to us for examination. Amongst them was the subject of this note.

The specimen is complete and, preserved in 5 per cent formalin as we received it, was almost exactly the size of the type, 130 mm. long and 6 mm. wide at the widest point over the parapodia. It has over 350 segments, much crowded and difficult to count at the posterior end. The general body colour is an ivory white, against which the purplish-brown tentacular and dorsal cirri stand out conspicuously. There is no evidence of the collateral budding

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in the terminal region which is a characteristic of the type specimen. In addition to its large size its quite distinctive feature is the form of the prostomium. This does not in our specimen conform exactly with Johnson's figure, but is sufficiently near to leave no doubt as to the specimen's identity. Its form is shown in Figure 1. The anterior eyes are wider apart and distinctly larger

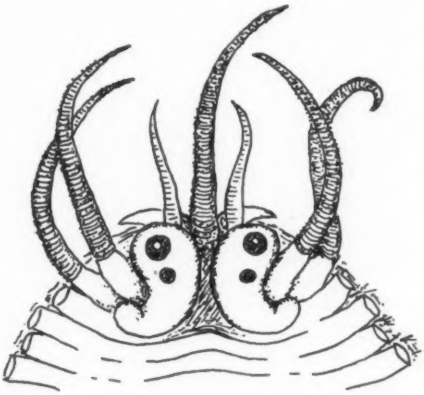

FIGURE 1. *Trypanosyllis ingens* Johnson. Head.

than the posterior pair. The palps are smooth and uncoloured, the lateral tentacles also uncoloured but moniliform, the median tentacle and tentacular cirri moniliform and deeply coloured. Beyond this we can add little to Johnson's description. It may, however, be useful to summarize some of the more salient features. The pharynx is well chitinized and ends in a trepan of ten teeth, no isolated large pharyngeal tooth can be made out. The trepan is surrounded by a ring of ten long papillae with rounded ends. The parapodia are short and are supported by a group of four acicula. The dorsal cirri are long and heavy, with articles short and crowded. They are roughly of two lengths, the longer ones having about thirty-six articles, the shorter rather more than half that number. They are not regularly alternated, several of approximately one length often occurring in groups. The setae are as figured by Johnson, they are uniform throughout the body, the terminal pieces having no trace of secondary tooth. As many as fifteen may occur in a parapodium.

The species most nearly approaching *T. ingens* Johnson is the common antarctic form *T. gigantea* (McIntosh). Both are large species (according to Monro, 1936, *T. gigantea* may attain 200 mm. in length) and both have unidentate setae. The form of their prostomia clearly differentiate them. Moreover *T. ingens* reproduces by means of bunches of stolons budded from a few posterior segments, whilst those of *T. gigantea* are produced in terminal chains (Monro, 1936). In addition to *T. ingens* the following species have been described from western America. *T. gemmipara* Johnson (Johnson, 1901),

T. intermedia Moore (Moore, 1909, a and b), *T. adamanteus* Treadwell (Treadwell, 1914), *T. taeniformis* (Haswell) (Monro, 1933). *T. ingens* differs from all of these in the form of the prostomium, and from the two first in coloration and in the character of the setae, both having a heavy secondary tooth in the terminal piece. *T. intermedia* and *T. adamanteus* are relatively small species. *T. intermedia* has bifid setae and *T. taeniformis* is distinct in coloration and in having the pharynx only slightly chitinized (Monro, 1933). The prostomium, setae, method of reproduction, and coloration clearly differentiate *T. ingens* from the European *T. zebra* Grube.

Note. Since the above was written Mr. Pike has collected and examined a large number of holdfasts from *Nereocystis* plants in Quatsino Sound. A second small example of *Trypanosyllis ingens* was found. Its prostomium is not so prominently recurved posteriorly as that of the larger specimen. This is probably a sign of immaturity.

REFERENCES

JOHNSON, H. P. The Polychaeta of the Puget Sound region. *Proc. Boston Soc. Nat. Hist.*, **29**, 381-437, 1901.

Collateral budding in Annelids of the genus Trypanosyllis. *Am. Naturalist,* **36**, 295-315, 1902.

MONRO, C. C. A. The Polychaeta Errantia collected by Dr. C. Crossland at Colon, in the Panama region, and the Galapagos Islands during the expedition of the S.Y. "St. George". *Proc. Zool. Soc. London*, Pt. 1, 1-96, 1933.

Polychaete worms. Discovery Reports, **12**, 59-198, 1936.

MOORE, J. P. Polychaetous Annelids from Monterey Bay and San Diego, California. *Proc. Acad. Nat. Sci. Philadelphia,* **61**, 235-295, 1909a.

The Polychaetous Annelids dredged by the U.S.S. "Albatross" off the coast of Southern California in 1904. 1. Syllidae, Sphaerodoridae, Hesionidae, and Phyllodocidae. *Proc. Acad. Nat. Sci. Philadelphia*, **61**, 321-351, 1909b.

TREADWELL, A. L. New Syllidae from San Francisco Bay collected by the U.S.S. "Albatross". *Univ. California Pub. in Zoology,* **13**, 235-238, 1914.